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VEGETABLE CROPS

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BY

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PREFACE

In the preparation of this book the author has had one main purpose; namely to meet the needs of college and university teachers of vegetable gardening for a textbook which brings together the results of experimental and research work. While vegetable gardening has been given less attention by scientific workers than most other important branches of agriculture, there is a large amount of experimental evidence available that has never been brought together. This material has not been used by vegetable gardening teachers to the extent that it should, largely because it is so scattered through the literature of the past forty years. The author has studied the literature and has attempted to give the experimental evidence available on the subjects discussed. On many subjects discussed no experimental evidence was found, and in these cases, the author has given what he believes to be the best information available.

The author believes that college and university teaching should be based mainly on principles of growing and handling vegetables rather than on detailed directions for performing the various operations. The emphasis should be on the science rather than on the art of gardening. Proficiency in the art of gardening can be acquired only by practice, and it is impracticable for the college to give the student sufficient practice in all phases of gardening to make him proficient. It is entirely practicable to teach students principles upon which successful gardening practice may be based and this is the contribution that the college should make. It is clearly recognized that some practice is necessary to a thorough understanding of the principles involved. The socalled practical exercises or laboratory work should be so planned and conducted as to bring out the principles taught, rather than merely to teach the student how to perform a given piece of work. The author has attempted to outline the best practice and to back this up with experimental evidence where such evidence is available.

In the preparation of this book extensive use was made of the material presented in publications of the various state experiment stations and the United States Department of Agriculture, and in scientific journals. Credit has been given for the material used. The author wishes to express his appreciation for helpful suggestions from his colleagues and others, especially to Dr. Paul Work, Dr. E. V. Hardenburg, and Professor H. W. Schneck. Acknowledgement is made to Masters Planter Co., for Fig.

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H. C. Thompson.

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CHAPTER I

VEGETABLE GARDENING

Vegetable gardening is one of the branches of horticulture and is also known by the technical name *olericulture.* Olericulture is usually defined as the science and art of growing vegetables, but as it is now taught and practiced it includes more than growing crops. In general, it may be said to include growing, harvesting, grading, packing, transporting, storing and selling or merchandizing vegetables. Selling or merchandizing problems belong to the science of economics rather than to vegetable gardening.

Vegetable growing is an important phase of agriculture and is increasing at a rapid rate. The value of all farm crops grown in the United States in 1919 was $14,755,364,894, while the value of vegetables grown on farms was $1,302,199,688. The area devoted to vegetables on farms in the United States in 1919 was less than 2 per cent of the total crop land, while the value of the vegetable crops was nearly 9 per cent of the total value of all farm crops. This includes the value of vegetables grown in farm home gardens. In 1919, 78.9 per cent of the farms, or 5,090,293, in the United States had farm gardens and the average value was $68. In addition to vegetables grown on farms there are hundreds of thousands of home gardens in cities and towns that are not included in the census report.

Vegetable gardening may be divided into five divisions based upon the objects sought and the methods employed in producing vegetables. These divisions are: (1) Truck gardening, (2) market gardening, (3) canning crops production, (4) vegetable forcing and (5) home gardening.

TRUCK GARDENING

Truck gardening may be defined as the growing of a special vegetable crop, or a few crops in relatively large quantities for a distant market. In general, truck gardening is extensive as compared to market gardening, but in the production of some truck crops, as celery, lettuce and onions, the most insive methods are employed.

The factors that should govern the selection of a location for truck gardening are: (1) Suitable climate for the crop or crops to be grown, (2) good transportation facilities to the market, and (3) desirable soils.

Climate as a Factor in Truck Gardening.—In any given region only those crops are grown, for long distance shipping, that are especially adapted to the climate. In other words, in truck growing a region is selected because of special climatic conditions. Many trucking regions in the South and in California have become important because of favorable climate for the growing of vegetables during the winter and early spring. Other regions have become important because the climatic conditions are especially favorable for a particular crop, as Rocky Ford, Colorado and the Imperial Valley of California for muskmelons. In these regions the climate is favorable for the development of high quality in the melons, and, it is less favorable to the development of muskmelon diseases than are the more humid regions.

In general, the important regions of production of any given vegetable crop are important because the climate is especially well suited to that crop. The climatic conditions that are influential are temperature, rainfall, humidity of the atmosphere, and light intensity. The ratio of rainfall to evaporation is important in regions where irrigation is not practiced.

Transportation as a Factor in Truck Gardening.—Since in truck gardening the vegetables are produced long distances from the markets good transportation facilities are essential to success. The selection of a location for a truck gardening enterprise, within the regions having suitable climatic conditions, is determined largely by the transportation facilities. These should include through freight service by railroad or boat lines, good refrigerator service for long distance shipping, express service in some cases, and good roads from the farms to the loading points.

The early development of truck gardening was along railroad and steamboat lines leading out from the larger eastern cities, especially in New Jersey, Delaware, Maryland and Virginia. According to the census report for 1900 the Steamer Roanoke in 1854 carried the first shipment of 200 barrels of garden truck from Norfolk, Virginia to New York. To secure proper ventilation these packages were carried on deck so that the quantity which could be transported was very small. The boats required 36 hours to make the trip. At the present time large boats with up-to-date refrigeration equipment carry thousands of packages between decks and make the same trip in one-half the time.

While vegetables have been shipped short distances by rail for a long time, it was not until the refrigerator car was perfected that the long distance transportation of perishables became possible. The first experiments in the use of ice during transit were made in the fifties, but it was not until the eighties that the carrying of vegetables in refrigerator

cars began. The first all rail shipment of vegetables to New York City from Norfolk, Virginia, was in 1885; from North Carolina in 1887; and from Charleston, South Carolina, in 1888. Without refrigeration it would have been impossible to develop the trucking industry in regions located long distances from the market, as in the South and West.

The Soil as a Factor in Truck Gardening.—The character of the soil is often an important factor in determining the location of many truck growing enterprises, as that of the production of celery, lettuce and onions on muck soils in New York, Ohio, Indiana, Michigan and other states. Since the truck grower is handicapped by distance from market, he must have some advantages in order to compete successfully with the market gardener. In most instances the truck grower has the advantage of a suitable climate and the best of vegetable soils. Within the region having a climate well-suited to the crops to be grown, the truck grower should determine the exact location on the basis of the soil, provided, of course, that suitable transportation facilities are available. The kind of soil to select depends upon the crops to be grown, and the time they are wanted for the market. For early crops a sandy loam soil is desired, but where earliness is not as important as large yields a soil more retentive of moisture is preferred.

Trucking Regions of the United States.—Blair (13) mentions five distinct trucking regions of the United States as follows:

1. Atlantic Coast States. This includes all of the trucking districts from the eastern shore of Maryland to Florida.

2. The Gulf States. This includes Alabama, Mississippi, Louisiana and Texas.

3. Pacific Coast States. California is the most important state in the United States in the production of truck crops. Portions of Oregon and Washington also produce some vegetables for distant markets.

4. The Interior Southern States. This region includes important trucking districts in Kentucky, Tennessee, Arkansas, Oklahoma, Arizona and New Mexico.

5. The Northern States east of the Rocky Mountains (including Colorado). This region includes the important muskmelon section of Colorado, the important onion and celery centers of Michigan, Indiana, Ohio and New York, the great cabbage centers of New York and Wisconsin, the great potato sections of Colorado, Minnesota, Michigan, New York and Maine. This region also produces a large part of the peas, sweet corn and tomatoes grown for canning.

The South Atlantic and Gulf Coast States and California are pre-eminently the winter garden areas of the United States. The Interior Southern States are important as producers of various vegetables for spring and early summer use. The Northern States East of the Rocky Mountains produce a large part of the vegetables which go on the market

in the fresh state in late summer and fall, as well as the bulk of the potatoes, cabbage, onions, celery and all other vegetables that are stored for winter use.

MARKET GARDENING

Market gardening may be defined as that branch of gardening which has for its object the production of vegetables for a local market. It is more intensive than truck gardening, and is usually practiced on high-priced land. The high land value is due mainly to the location. A large percentage of the market garden land is near enough to large cities to be valuable for building lots.

The market gardener usually grows several vegetables, and, in many cases, two or three crops of the same vegetable are grown during a season. Since he caters to a local market it is desirable for the market gardener to have a continuous supply of vegetables for a large part of the season in order to hold his trade. The market gardener must be a good all around gardener rather than a crop specialist, and, to be successful, he must be a good salesman since he usually sells his own products.

Development of Market Gardening in the United States.—In the early days, when the population was scattered and there were no cities and towns each family produced its own vegetables. As towns and cities sprang up market gardening developed to meet the needs of those members of the population who had no land. For a long time this industry was confined to the immediate vicinity of the cities, but as the population increased and the demand for vegetables grew the area was greatly enlarged. However, until comparatively recent times (since 1900) most market gardens were within 10 to 15 miles of the cities, but with the building of good roads and the development of the motor truck the market gardening area has been greatly extended. At the present time (1923) market gardening is carried on 30, 40, 50 and even 75 miles from the consuming centers and the produce is hauled direct to market by motor trucks.

Prior to 1860 market gardeners supplied a large part of the vegetables consumed in the cities, for truck growing was almost unknown at that time, except to a very limited extent along the railroad and steamship lines leading out 50 miles or so from a few of the larger cities. While the market garden areas around many of the large cities are increasing in size, market gardening is not developing as rapidly as truck gardening.

Selecting a Location.—The selection of a location is largely a matter of personal preference, since market gardening is carried on in the immediate vicinity of nearly all cities in the United States. In general, the market should be given first consideration. While the large cities provide the largest markets for vegetables they are not always the best, because

many of them are already supplied. Many of the smaller cities and industrial towns are poorly supplied with vegetables for a large part of the season. Such markets offer excellent opportunities to market gardeners.

After selecting the market the would-be market gardener should choose the exact location with reference to the city or town. In making this choice he should consider the kind of soil, the price of land, the tax rate, the distance from market, the character of the roads, the topography of the land, the exposure, the possibility of getting a supply of labor, the water supply and the general character of the community from the social standpoint. Other things being equal low-priced land is desirable, but the other factors should be considered along with price. Distance from market should be measured in time required to reach it rather than in miles. A garden located 15 miles from market on a good road is preferable to one on a bad road much nearer to market. Level or gently rolling land is preferred to hilly land since the latter is difficult to work and is subject to erosion. When earliness is an important factor, as it is in most market gardening, a southern or eastern exposure is better than either a northern or western one.

CANNING CROPS PRODUCTION

The growing of vegetables for the canning factory is an important industry in the North and in sections of the West, especially in California. The most important vegetables used in canning are tomatoes, sweet corn, peas and asparagus, although a large number of other vegetables are canned in considerable quantities. The importance of the vegetable canning industry is indicated by the number of cases of canned vegetables packed and the value of the product as shown in Table I. The figures are from the census report for the year 1919.

TABLE I.—NUMBER OF CASES OF CANNED VEGETABLES PACKED IN THE UNITED STATES IN 1919 AND THE VALUE OF THE PRODUCT

Vegetable	Number cases No. 2 cans	Value	Vegetable	Number cases No. 2 cans	Value
Asparagus[a]	1,006,604	$ 6,571,629	Pumpkin[b]	383,211	$ 861,436
Beans, baked	11,142,331	28,551,342	Succotash	373,977	1,142,236
Beans, string	2,199,825	6,607,080	Sweet potatoes	841,813	2,477,719
Beans, kidney	429,104	1,429,680	Spinach[b]	676,388	2,338,497
Beans, all others	584,403	1,362,782	Tomatoes[b]	11,885,520	38,067,999
Lima beans	468,569	1,457,719	Tomato pulp[c]	739,055	3,819,101
Beets[b]	584,309	1,951,344	Tomato paste[d]	217,729	1,300,680
Corn	14,402,725	35,532,007	All other vegetables	634,220	1,672,518
Kraut[b]	1,202,125	2,845,340			
Peas	9,325,727	25,073,220	Total	57,097,635	163,062,389

[a] No. 2½ cans. [b] No. 3 cans. [c] Case contains 12 No. 10 cans. [d] Case contains 48 No. 1 cans.

Important Regions of Production.—The regions which have the most favorable growing conditions tend to become the leaders in the production of certain vegetables for canning. Other factors, however, have an effect on the development of the vegetable canning industry even where the growing conditions are not the most favorable. In many cases factories are located at certain points because of the supply of fruits available, but vegetables are also canned even though the conditions are not very favorable for their production.

In 1919 nearly all of the asparagus was packed in California. Indiana led in baked beans. New York canned the most string beans and was followed by Maryland, Wisconsin and California in the order given. Iowa was the leading sweet corn canning state, but was closely followed by Maryland and Illinois. Other important sweet corn states were, Maine, Ohio, New York, Wisconsin, Indiana and Michigan. Ohio led in the production of kraut, followed by New York, Wisconsin and Michigan. Wisconsin canned over half of the peas packed in the United States in 1919. Delaware, Maryland, Mississippi and Virginia were the leading states in sweet potato canning. California and Maryland canned over half of the tomatoes packed in the United States in 1919. Other important tomato canning states were Indiana, Virginia, Utah, Missouri and New York. In most instances the leading states have favorable climates and soils for the particular crop or crops in which they lead.

In growing canning crops large yields are more important than earliness, and unless a fairly large crop can be grown the growers will not continue in the industry, because, in most cases the price is set in advance and there is little or no chance to secure a higher price on account of short crops. Most vegetables for canning are grown on contract and the price is usually not more than enough to cover cost of production of an average normal yield. When the yield is below normal most growers lose money on the crop.

Methods of Production.—Vegetables for the canning factory generally are produced on a more extensive scale than when grown for the general market. Less intensive methods are followed with most crops grown for canning than is followed with the same crops produced for market. Most of the vegetable canning crops are produced by the general farmer, in rotation with grains and other standard farm crops rather than by the vegetable gardener. However, the market gardener and the truck grower, in some regions, often grow crops for canning. Since earliness is not usually very important heavier soils are selected for canning crops than for the same crops grown for the market. The heavier soils generally are richer and have a higher water-holding power than the sands ann sandy loams; hence they are more productive. The cost of productiod per acre and per ton is usually less for canning crops than for similar

crops grown for market, because of lower land value, less hand labor, smaller quantity of fertilizer, lower cost of handling. The lower cost of handling is due to the fact that the canning crops are not graded, cleaned or specially prepared, and there is either no expense or a very small expense for packages. In some cases the canners furnish packages, but even where they do not, the expense to the grower is relatively low because the packages are returned.

VEGETABLE FORCING

Vegetable forcing is the growing of vegetables out of their normal season of growth and is accomplished by means of artificial heat, or in some cases by means of protection from cold. Greenhouses are the common structures used for forcing vegetables, especially in the North, although hotbeds are used to a considerable extent in some sections for forcing lettuce, radishes and other small vegetables. In the South cold frames are used to a considerable extent for hastening various crops. Cloth-covered frames are used for considerable areas of lettuce in North Carolina and glass-covered frames are in use in the vicinity of Norfolk, Virginia for growing many vegetables, including cucumbers in the spring. Cellars, caves and specially built houses are employed in growing mushrooms and in forcing rhubarb and asparagus. These crops are forced in the dark so that glass is unnecessary.

Vegetable forcing has developed because of the demand for fresh vegetables out of season. It has grown up mainly as an adjunct to market gardening, although at the present time many greenhouse men do not produce any vegetables out of doors. The vegetable forcing industry has developed mainly in the eastern part of the country, especially the greenhouse forcing industry. Some of the important vegetable forcing centers are Boston, Massachusetts; Rochester, New York; Erie and Philadelphia, Pennsylvania; Ashtabula, Cleveland and Toledo, Ohio; Grand Rapids, Michigan; Chicago, Illinois; Terre Haute, Indiana; and Davenport, Iowa. Some vegetable forcing has developed around nearly all of the northern cities, and about many of the southern and western cities.

Since vegetable forcing is a very specialized industry requiring detailed treatment and discussion it is not further considered in this book.

HOME GARDENING

The production of vegetables for home use is the oldest branch of vegetable gardening and is still of very great importance. The value of the vegetables grown in the farm home gardens alone was $193,248,964 in 1919. In addition to these, there are hundreds of thousands, perhaps

millions, of home gardens in villages, towns and cities not included in the census report and the value of whose products is not known. More important than the value, as reckoned in dollars and cents is the relation of these vegetables to the health of those whose only available supply is that grown at home. Thousands of farmers and other dwellers in rural communities are unable to get fresh vegetables unless they grow them. Other thousands do not get fresh vegetalbes unless grown at home even though they can be purchased nearby.

It is often said that the general farmer can buy vegetables more cheaply than he can produce them, but it is a matter of common observation, that unless he produces them his family does without them. It may be true, in some cases, that it is cheaper to buy than to produce vegetables, but in most country communities fresh vegetables are not available in the stores. In most cases it is probably cheaper to produce vegetables on the farm than to buy them where they can be bought. Certainly no area of the same size on the general farm produces as much in real value as the well cared for home garden.

Location of the Home Garden.—Where there is an opportunity for a choice in the selection of a location of a home garden usually the question of nearness to the house should be given first consideration. As most of the work in caring for the garden is done in spare time the location selected should be as close to the house as practicable. Nearness to the house is also of importance in the gathering of vegetables, since this is usually done by the women of the family. In dry regions it is desirable to locate the garden where it can be irrigated easily and conveniently, and in cold, exposed sections of the country location with reference to protection from the winds is important. In most sections of the North a southern or southeastern exposure is desirable since the soils on these exposures warm up earlier in the spring.

Plan and Arrangement of the Garden.—The plan and arrangement of the garden should be determined by the size of the area to be used, the slope of the land and the kind of cultivation to be given. In a small garden cultivated by hand the rows may be closer together than for horse cultivation. The farm garden should usually be planned for horse cultivation and the area should be long and narrow rather than square. The rows should run the long way of the garden and it is desirable to have turning spaces at the ends.

The size of the garden depends upon the number of persons to be supplied, but it is better to have a small well-kept garden than a large one poorly cared for. By close attention to succession cropping and intercropping, ¼ acre of land may be made to supply a family of six. Where land is plentiful it is often desirable to set aside enough land to allow a part of the garden to be planted to a soil-improving crop each year, but this is not essential where plenty of manure is available.

The location of perennial crops such as asparagus, rhubarb and small fruits should be given careful consideration. These should be placed at one side or at one end of the garden where they will not be in the way when the garden is plowed. Long season crops or those occupying the land throughout the growing season should be planted together. Quick-maturing crops should be planted in contiguous rows so that the area may be planted to a single late crop. It is desirable to plant tall-growing crops together and locate them so they will not shade the lower-growing crops.

A plan should be made on paper before undertaking the planting of the garden. This plan should show the location of all of the crops, the amount of space devoted to each, the crops that are to follow the early ones and the distance between the rows. It should be possible to calculate from the plan the quantity of seeds required for each vegetable.

CHAPTER II

SOILS AND SOIL PREPARATION

The soil is the storage house for certain elements and compounds used by the plants, as well as the home of the plant roots. Therefore, the physical and chemical composition of the soil is of prime importance in crop production. The chemical composition can be changed by adding fertilizers and other materials and to some extent, by drainage and tillage, which favor aeration. The physical condition of the soil is improved by drainage, by tillage and by incorporating organic matter, or by mixing in other soils as sand in clay, or muck in either clay or sand. Unless the soil is in good physical condition large yields cannot be secured. Fertilizers, good seed and the best of care, will not insure success unless the soil is of the right texture and is well prepared.

KINDS OF SOILS

Practically every kind of soil is used for vegetable production in the United States, but some are considered better than others. A sandy loam soil is considered best, but no one type is best for all crops under all conditions. Every type of soil has its advantages and disadvantages. The soils preferred for vegetable production are sandy, sandy loam, clay loam, silt and muck.

Sandy Soils.—A sandy soil is an early soil, because it dries out early in the spring and therefore warms up earlier than the finer soils. It is valuable for growing very early crops which do not require a long season. This type of soil is naturally poor, requiring heavy manuring and fertilizing for good results. It dries out quickly, therefore is not suited to long season crops, or those commonly grown during the drier part of the year. The finer sandy soil, such as the Norfolk fine sand, is used quite extensively for vegetable growing, but for good results in producing midseason crops, manure or other humus-forming material must be used in large quantity to make the soil retentive of moisture.

Sandy Loams.—This type of soil is used more for truck growing and market gardening than any other type and for general use it is considered best. It is more retentive of moisture than the sands, but is not quite as early. However, the small disadvantage in earliness is more than offset by the other factor mentioned. Sandy loam soils, while usually somewhat poor, are richer than the sands. All soils of sandy

nature can be prepared earlier in the spring and sooner after rains than any of the soils containing considerable clay. The sandy sorts while still wet do not puddle and bake when plowed, harrowed or cultivated. This is a decided advantage in growing vegetables, because a few days' delay in getting on the land in spring may, and often does, mean the difference between profit and loss.

Clay Loams.—Clay loam is more retentive of moisture than either the sand or the sandy loam and is naturally richer. It is not as early because it holds moisture longer in the spring, therefore does not warm up as readily as the sands and the sandy loams. Clay loams are not suited to growing crops where earliness is a prime consideration. Because of its water-holding capacity and because it is naturally richer than the sands and sandy loams, a clay loam is valuable for crops grown during the dry portion of the season especially where large yields are more important than earliness. Late cabbage, late potatoes, late sweet corn, tomatoes and peas for the cannery are grown quite extensively on this type of soil. A clay loam must be prepared and cultivated just at the right time to prevent baking and breaking up in lumps.

Mucks and Peats.—Muck is composed of organic material made up of partially decayed plant remains that have accumulated in wet places. The terms muck and peat are often used indiscriminately but the former term should refer to an organic soil that has undergone decomposition to such an extent that the plant remains are no longer recognizable. Muck soils should not be confused with those mineral soils of a mucky nature containing considerable humus, but which are not combustible. True muck will burn when dry.

The chief characteristics of muck are:

1. It is predominately organic in nature, containing 50 to 85 per cent combustible material when dry.
2. It is brown or black in color and the more advanced the stage of decomposition the darker the color.
3. It has a high water-holding capacity, absorbing 60 to 85 per cent of its volume and 300 to 1,000 per cent of its weight of water.
4. It is generally rich in nitrogen. Most of the muck soils that are under cultivation contain from 1½ to 2½ per cent of nitrogen in organic form. Many deposits contain much more than this.
5. Muck is usually low in mineral elements, especially potash. All deposits that have been tested are poor in potash, which is the main limiting factor.
6. Muck is a late soil because of its high water-holding capacity and it is subject to late frosts in spring and early frosts in fall.

For the production of certain vegetables, especially celery, lettuce and onions muck soils are considered better than any others. A large portion of the celery, lettuce and onions grown as truck crops in the North, is produced on muck soils. Carrots, beets, parsnips, spinach, cabbage, potatoes and other vegetables are grown to some extent on muck soils.

Muck soils are easily tilled, can be worked soon after rains, do not bake, are rich in nitrogen, and being loose, root crops grow straight and symmetrical.

Muck soils are not suitable for tender, long-season crops, because frosts are likely to occur earlier in the fall and later in the spring than on upland soils. It has been assumed that this is due largely to the low elevation of the muck. Bouyoucos (14) has given a brief summary of results of studies made in Michigan which show that other factors are also responsible for lower temperatures on muck than on surrounding mineral soils. He reports as follows:

It is a very common experience with farmers and gardeners working with muck and peat soils, that when a frost occurs during the growing season plants which are easily susceptible to freezing, such as corn and strawberries, are almost always injured or entirely killed by it. On the other hand, the same kind of plants growing on mineral soils such as clay loam, sand, etc., located very close to and on the same level as the muck and peat soils, usually are not injured by the frost, unless it is very heavy. For instance, 2 years ago corn growing on muck land at the College farm was killed almost completely by an early frost in the fall, while the corn growing on the adjacent loam soil which was very close to and almost at the same elevation as muck land, was not at all injured. The question now is why should the plants freeze more easily on the mucks and peats than on the mineral soils.

In order to be able to answer this question the Soils Department of the Michigan Agricultural College a few years ago started some experiments to study the subject. It may be of interest to muck farmers and gardeners, and perhaps to others, to know what these findings are. In a few words, the experiments seem to prove that the main reason the plants freeze more easily on a muck than on a clay is that the muck does not manage to keep its surface and the air above it as warm during the night as does the clay. For instance, in a night during September when frost occurred, the temperature of the muck right at the surface was 4 degrees below freezing while the temperature of the clay was almost 5 degrees above freezing. During the day both soils had the same temperature. Now when a soil has a high temperature at the surface during the night it helps to warm up the air above, and to prevent a frost. The clay, therefore, which manages to keep its surface warm will prevent a frost, while the muck which allows its surface to become cold, will permit a frost. Plants, therefore, freeze more easily on mucks and peats than on mineral soils.

The reason that the mineral soils, such as clay, loam and sand, manage to keep their surface warmer than the mucks and peats is that the mineral soils allow the heat to travel through them faster than do the mucks and peats. The heat which is stored in the lower depths during the day comes to the surface during the night, and the mineral soils which allow the heat to travel faster manage to keep their surface warmer than the mucks and peats which allow the heat to travel through them very slowly. These facts are well illustrated by the following results—when all the soils got coldest at the surface during the night the temperature of the clay at the surface was 36.2 degrees F. and that of the muck

28 degrees F. At 6 inches below the surface, however, the temperature of the clay was 46.5 degrees F., while that of the muck was 51.4 degrees F. These figures show, therefore, that even though the muck is about 5 degrees warmer than the clay at 6 inches below the surface, yet on account of the poor ability of the muck to conduct this heat, it allowed its surface to become about 5 degrees colder than that of the clay.

We are now conducting experiments to find the best and most practical ways of increasing the ability of the mucks and peats to conduct heat faster and thereby prevent or minimize the damage of frost to plants. At present packing the soils and maintaining a high moisture content appears to be among the most promising methods. In some of the experiments packed muck was more than 3 degrees warmer at the surface than cultivated muck during a frosty night.

The influence of water content is well exemplified by the following observation. In the fall of 1920 corn growing in a basin of muck land, where the drainage was very poor, the water table and moisture content high, was hardly touched by a frost, while the corn growing on the surrounding muck land with a slightly higher elevation and much drier was completely killed by the frost.

Not all mucks are valuable for vegetable growing. Their value depends upon the stage of decomposition, the character of the material from which the soil was formed, the drainage and other factors. In general, the more decomposed the material the better the muck for vegetable growing. It is believed by many authorities that muck soils which have supported a growth of deciduous trees and shrubs are better than those which have grown coniferous trees. A peat which contains a large amount of material from coniferous trees decomposes more slowly than one which does not contain such material. This is probably due to the resins in the conifers, which preserve the woody materials. Some muck soils are toxic, usually on account of the underlying rock and are nearly useless for growing vegetables.

Drainage and tillage are important factors in the decomposition of the organic material in muck soils. Removing the water and stirring the soil allow air to enter which favors the growth of organisms that cause the breaking down of the plant remains. Oxidation itself is of importance. Lime also favors decomposition when the soils are sour for the desirable organisms do not thrive well in an acid soil. Stable manure has been found very beneficial on newly-cleared muck soils because of the presence of beneficial organisms in the manure. The manure may therefore be considered as an inoculant or at least a carrier of beneficial organisms.

For the first few years after muck is cleared it is advisable to grow some general farm crop, such as corn or hay, rather than vegetables. The latter do not thrive well on new muck and the roots and trash interfere with planting, cultivating and harvesting the more intensively cultivated vegetables. Two or three years of tillage will usually put most muck soils in good condition for onions, celery and lettuce.

Importance and Distribution of Muck.—It has been estimated that there are approximately 138,000 square miles or nearly 90,000,000 acres of swamp land in the United States, a large part of which is muck or peat (37). The muck and peat deposits are more abundant in the Northeast than in other sections of the country. The main deposits are north of a line extending westward from about the southern boundry of New York nearly to the ninetieth meridian. Other deposits are found in a narrow strip along the Atlantic coast to and including Florida and small areas occur in California, Oregon and Washington. There are small deposits in other states but these are not of much importance. Michigan, Wisconsin and Minnesota contain the largest areas of muck, but only a very small part of this is cleared. In fact only a very small percentage of the muck deposits of the United States is under cultivation and most of this is used for general farm crops. This is as it should be, for if 2 per cent of the muck land acreage was planted to the three most important vegetable crops there would be serious overproduction with resultant low prices for the products.

Silts.—Silt soils are valuable for the production of some vegetables, especially those requiring a rich, relatively moist soil. Late cabbage, sweet corn for the cannery, rhubarb and horse-radish do especially well on this type of soil, the last because a deep rich soil is important to growth of good, straight roots. River-bottom lands often contain silt and silty loam soils which are enriched by the deposit of sediment from the rivers during over-flow periods. Where large yields are more important than earliness silt soils of river bottoms are very desirable, although the abundance of weeds is one disadvantage on such lands. The lighter silts are valuable for root crops such as beets and carrots, and these crops are often grown on such soils.

SOIL PREPARATION

Thorough preparation of the soil is essential to successful production of nearly all farm crops and is especially important in the growing of vegetables. Poor preparation usually results in an inferior stand of plants regardless of the quality of the seed and no amount of after cultivation will take the place of good preparation. Among the operations considered are drainage, plowing, harrowing, dragging and rolling. Clearing the land might be considered also, and, in irrigated regions, leveling undoubtedly would be considered as a part of preparation but these are not considered here.

Drainage.—For wet soils the first operation in the preparation should be drainage as most soils cannot be properly prepared when poorly drained. Good drainage is essential to success in growing practically all vegetables, although some crops stand wet soils better than others, and a

few minor crops, such as water cress, thrive in a very wet soil. Good drainage is especially important for early vegetables because earliness is not possible in a wet soil. The sands are of value in growing early vegetables because they are better drained than the heavier soils. On soils not naturally well drained artificial drainage is a profitable investment. It is much better to drain the soil by means of ditches or tile drains than to plant the crop on ridges. Drainage not only removes the excess water, but also allows the air to enter the soil and air is essential to the growth of beneficial organisms which make some of the nutrients available to the plants. Drainage also allows the soils to warm up earlier in the spring, thus favoring earlier preparation and planting.

Plowing.—Soils for vegetables should be deep, therefore, deep plowing should be practiced where practicable. The deeper the soil the more moisture it will hold and the greater the feeding area of the roots. A soil that has been plowed only a few inches deep should be deepened gradually, because too much of the subsoil turned to the surface is usually injurious. It is best to deepen the soil by plowing an inch deeper each year until the desired depth is reached. A depth of 8, 10 or even 12 inches is desirable on most soils used for vegetables, but this depth is not necessary on muck soils.

The time for plowing depends somewhat on the kind of soil and on the climatic conditions. Fall plowing is desirable on all soils where it can be practiced and especially where sod is to be turned under. The advantages of fall plowing are: (1) To reduce erosion by collecting water in the unbroken furrows; (2) to improve the physical condition of heavy soils by exposing them to frost action; (3) to aid in the control of insect pests by exposing them to the weather; (4) to relieve the pressure of spring work; (5) to make possible the earlier preparation of the soil for planting; (6) to bring about the decay of coarse vegetable matter turned under. Coarse material turned under in the spring is of little value to early crops and may be actually injurious by cutting off the capillary movement of water. Fall plowing in the South is not as desirable as in the North due to the loss by leaching where the soil does not freeze. In the South the effects of freezing and of alternate freezing and thawing are not as important as in the North. Where shallow plowing is practiced, as in many regions of the South, fall plowing is not desirable, especially on hilly land because the whole furrow slice often slides down the hill and leaves the subsoil exposed. Sandy or sandy loam soils are not as much benefitted as clay soils by fall plowing even in the North because frost action is not especially important on soils that are naturally friable.

Spring plowing should be done as early as the soil will permit, but great care should be exercised not to plow when the land is too wet. This is especially important on clay soils. No soil, containing a considerable portion of clay, should be plowed when wet nor should such a soil be

allowed to get too dry before plowing. If plowed too wet such soils will puddle and bake and will be very difficult to get into good condition. If allowed to get too dry, clayey soils break up in hard lumps which are difficult to pulverize by harrowing. A soil is in good mechanical condition for plowing if after being compacted in the hand it gradually crumbles when the pressure is released. If it is moist enough to retain its form after the pressure is released it is too wet for plowing.

Harrowing.—After spring and summer plowing the ground should be harrowed as soon as possible to make the surface loose and friable. The condition of the soil should determine the type of harrow to use immediately after plowing. A disk harrow is especially valuable on heavy clay soils and on sod land because it thoroughly pulverizes the soil to a considerable depth. After disking the soil is usually smoothed by a spike-tooth, Acme, or spring-tooth harrow. The spike-tooth harrow is satisfactory for leveling and smoothing the surface but is a poor implement for pulverizing the soil as the teeth do not go deeply enough and clods and lumps pass between the teeth. The spring-tooth harrow is an important implement on stony ground. It is a good pulverizer and leveler. The Acme harrow is a good implement because it not only pulverizes the soil to a considerable depth, but also leaves the surface smooth. It is not satisfactory on stony ground. The Meeker smoothing harrow is almost indispensible in intensive gardening as a finishing harrow. It is not at all satisfactory for anything except to fine and smooth the surface, but should be in more general use for this purpose. The Meeker leaves the surface in as good condition as a garden rake and is much more economical. It pulverizes the soil to the depth of 2 or 3 inches, breaks up the smallest clods and by means of an adjustable board across the middle it levels the soil and leaves it in a smooth condition. This harrow is often used just before seed sowing and transplanting.

The thoroughness with which the soil is prepared before planting determines to a large extent the ease and efficiency of cultivation, but no amount of cultivation will make up for poor preparation. Timeliness is of the greatest importance in all operations concerned with soil preparation and cultivation. The moisture content of the soil determines to a considerable extent the efficiency of the work done by the harrow. If the soil is too dry a large percentage of lumps will not be crushed and if too wet the soil will become puddled. Harrowing the soil almost immediately after plowing will prevent surface baking and reduce the loss of moisture by evaporation as the loose soil checks the upward flow of moisture. In summer, harrowing immediately after plowing is of much more importance than in early spring because usually there is ample moisture in the soil early in the spring, but very seldom is this the case in mid-summer or late summer. Of course, the foregoing statements refer to humid regions. In irrigated regions it is always important to harrow

the land to prevent loss of moisture since water is expensive and often scarce.

Dragging and Rolling.—Heavy soils often break up in clods and lumps, which are very difficult to crumble with any type of harrow. By use of a heavy drag or roller the lumps may be crushed with comparative ease. In preparing the soil late in the season the drag is often used immediately after the plow, and then followed with the disk or spring-tooth harrow. In some instances the drag or roller is used before and after the harrow in order to crush the lumps brought to the surface by the harrow. The main use of the drag or roller on heavy soils is to crush the lumps, but on light soils both are often used to pack and smooth the soil. On muck soil the usual practice is to use a drag or planker, as it is often called, just before planting in order to level and smooth the surface. In this case the drag need not be as heavy as when used for lump crushing, unless packing of the soil is also an important consideration.

CHAPTER III

MANURES

Stable manure or barnyard manure was practically the only fertilizing material applied to the soil in the early days of commercial gardening in the United States. In fact it is still the main reliance of market gardeners in most sections. However, with the increase in acreage of land planted to vegetables and the decrease of horses in cities the manure supply is inadequate to furnish sufficient fertilizing material, or sufficient humus to keep up production. From what has been said it is evident that the greatest economy in the care and use of manure should be practiced. Under present prevailing methods market gardeners are especially dependent upon the use of manure to supply humus.

With high-priced land, growers must follow intensive methods and utilize their land to the fullest extent for growing money crops. These money crops occupy the land practically throughout the growing season, so that it has not seemed practicable to most gardeners to grow a green crop to turn under. This, however, will have to be done or else the vegetable growing industry must move farther from the cities where land is less expensive in order that soil-improving crops can be grown economically.

Manure is of value as a source of humus, as a carrier of nitrogen, phosphorus and potash and as a promoter of useful organisms.

Manure as a Source of Humus.—Vegetable growers would not be justified in buying manure for its nutrient value alone under most conditions. The elements, nitrogen, phosphorus and potash can be bought more cheaply in chemical fertilizers than in manure when the cost of hauling and applying are taken into consideration. Manure, however, is the most valuable source of humus available and some form of organic matter is necessary to keep the soil in good condition. Manure improves clay soils by making them looser and more friable, thus improving drainage and aeration. It improves sandy soils by filling spaces between the soil particles with humus and therefore makes them more retentive of moisture. By heavy applications of manure to sandy soils vegetable growers are able to produce good crops which would be impossible without manure or some other source of humus.

Manure as a Carrier of Nitrogen, Phosphorus and Potash.—As a carrier of nitrogen, phosphorus and potash the value of the manure depends, (1) upon the kind of manure, (2) the amount and kind of bedding

or other material mixed with it and (3) the care the manure has had before being applied to the land.

Hart (62) of the Wisconsin Agricultural Experiment Station gives the average composition of fresh manure including both solid and liquid excrement of farm animals as shown in Table II.

TABLE II.—AVERAGE COMPOSITION OF FRESH MANURES

Animal	Water, per cent	Nitrogen, per cent	Phosphoric acid, per cent	Potash, per cent
Sheep	64.0	0.83	0.23	0.67
Horse	70.0	0.58	0.28	0.53
Pig	73.0	0.45	0.19	0.60
Cow	77.0	0.44	0.16	0.40
Mixed	75.9	0.45	0.21	0.52

A ton of horse manure of average composition contains approximately 10 pounds nitrogen, 5 pounds phosphoric acid and 10 pounds of potash. Hen manure, analysis of which, is not given in the above table contains about 55 per cent water, 1 per cent nitrogen, 0.80 per cent phosphoric acid and 0.40 per cent potash. From the standpoint of nutrient value hen manure ranks first and sheep manure second. Horse manure, however, is the only kind commonly available by purchase to vegetable growers. The other manures are produced mainly on farms and are used there, whereas horse manure is produced also in cities and is sold to market gardeners and others.

Manure as a Promoter of Useful Organisms.—Manure has some value in addition to its humus and its nitrogen, phosphorus and potash but this additional value is hard to estimate. It contains organisms which break down the organic matter of the manure itself and aids in the decomposition of the humus in the soil. In the decomposition of organic matter acids are set free, which act on some of the mineral compounds and make them more readily available to the growing plants. On new muck soil manure seems to have a beneficial effect greater than can be accounted for on the basis of the important chemical elements contained in the manure. This effect may be due to the organisms present in the manure, acting on the organic constituents of the muck soil, especially in changing the organic nitrogen to nitrates which are available to plants. It is well known that decaying manure contains large number of organisms, including bacteria, yeasts and molds.

Losses in Manure.—The analyses given in Table II do not take into consideration losses incident to the ordinary handling of manure. There are three causes of losses: (1) Loss of urine by drainage from the stable

or yard, (2) loss of soluble material by leaching, (3) loss of nitrogen by fermentation. About 50 per cent of the fertilizing value of the excrement from farm animals is in the urine, therefore every effort should be made to save it. The elements are present in a more readily available form in the urine than in the solid excrement. The loss of nutrients by leaching may be as much as 60 to 70 per cent in 6 months if unprotected. It is safe to say that under the usual careless manner of storing farm manures out of doors at least 50 per cent of the value of the nutrients is lost. Part of this loss, if not most of it, can be prevented by proper piling to prevent rain water from running through the pile and nutrients being lost in drainage water. The loss by leaching is due to the loss of nitrogen, phosphorus and potassium compounds in both liquid and solid portions of the manure.

The loss by fermentation is in the nitrogen compounds. This loss is due to changes brought about by micro-organisms, especially bacteria, yeasts and molds breaking down the organic compounds into ammonia which escapes into the air as gas. This gives the characteristic odor to fermenting manure. Under most favorable conditions about one-sixth of the nitrogen in manure is lost during decomposition and under average conditions probably at least one-half of the nitrogen found in fresh manure is lost before it reaches the soil.

Fresh Manure Versus Rotted Manure.—From the discussion of the losses in storing it would seem to be the best practice to apply manure to the land as soon as produced, but this cannot always be done nor is it always desirable. Among the advantages of using manure while it is fresh are: (1) There is little loss of valuable materials through leaching and decomposition, (2) some insoluble materials in the soil are made more soluble by the decomposing manure coming into contact with the soil particles, (3) desirable organisms are supplied in the fresh manure, (4) the texture of heavy soils is improved, and (5) the growth of foliage is favored and therefore the yield of crops grown for their stems and leaves is increased. Among the disadvantages of fresh manure might be mentioned: (1) Unfavorable effects on the soil when applied in large quantities; (2) burning effect on plants, due to rapid decomposition of urine in manure, especially in open porous soils; (3) carries weed seeds and germs of plant diseases.

Decomposed manure contains phosphorus and potassium in more available forms and in larger percentages than in fresh manure. The larger percentages are due to the fact that the organic matter has been reduced in amount by decomposition. The nitrogen in decomposed manure is not as readily available as that in the urine of fresh manure. Some of the advantages of decomposed manure are; (1) More even action and more evenly balanced combination of nitrogen, phosphorus and potash, (2) less likelihood to cause burning, (3) smaller bulk to handle for

same amount of fertilizing materials, (4) weed seeds largely destroyed during decomposition and (5) less interference with soil preparation and cultivation.

Composting Manures.—Vegetable growers very often pile manure in low flat piles and allow it to decay before applying it to the land. This is often necessary since the manure is hauled when it is not practicable to apply it to the soil due to the land being occupied by crops, or for other reasons. In addition to this, well-rotted manure is preferred for many crops, due to the fact that it can be better incorporated with the soil and interferes less with planting and cultivating than coarse manure.

When manure is piled and allowed to decay before using great care should be given to prevent leaching of the soluble materials and the loss of humus and nitrogen through fermentation. These can be prevented by stacking manure in compact, flat piles not less than four feet deep. With this depth there is little loss by leaching provided the sides and ends are nearly perpendicular and by keeping the manure compact and moist fermentation is controlled and loss of nitrogen is kept down. It is often necessary and is practically always desirable, to apply water to the pile of manure to prevent "fire fanging." The manure should be turned two or three times at intervals during the period it is piled in order to have uniform decomposition. In turning the manure, that from the inside of the old pile should be placed on the top or sides of the new one.

Piling manure as described is often termed "composting," but in the true sense of the word a compost is a mixture of materials as manure and soil, or manure and leaves or other litter. In making a compost fresh manure is piled in alternate layers with absorbent materials. One method of making a compost heap is to start with a few inches of loose soil or other absorbent material as a foundation and place on this a layer of fresh manure, then alternating layers of absorbent material and manure. Muck and peat are good absorbent materials and are used to a considerable extent in making compost in some of the European countries. In many parts of the United States these materials could be used to good advantage. The details of making a compost heap vary in respect to absorbent materials used, thickness of the layers, depth of the pile, etc. Sufficient absorbent material should be used to absorb the soluble material and the gases from the manure. The entire surface of the pile should be covered with a layer of soil to prevent loss of ammonia.

In making a compost heap it is advisable to make use of all valuable material that is available. Trimmings from vegetables, unless seriously diseased, garbage, straw, hay that is not suitable for feed, weeds, lawn clippings and leaves may all be added to the compost heap.

In a few weeks after the pile is completed it should be turned over and uniformly mixed and again covered with a layer of absorbent, unless it is

to be used at once. It is desirable to turn the pile two or three times before the compost is applied to the land.

Time to Apply Manure.—The proper time to apply manure depends on the kind and age of the manure, the stage of its decomposition, the crops to be grown and the rotations to be followed. When cow manure is to be applied it should be plowed under as far in advance of planting as convenient. Fall application is desirable if the land is to be plowed before winter. In the North it is not desirable to leave manure on the surface of the ground during the winter on account of loss due to leaching when the ground is frozen. Where vegetables are grown in rotation with general farm crops it is often best to apply the manure to the crop preceding the vegetable crop. Well-rotted manure, especially in small applications, may be applied to best advantage after the land is plowed but before harrowing. For hen and sheep manure this is unquestionably the best practice.

Amount and Method of Application.—The rate of application depends upon the supply of manure, the kinds of crops to be grown and the character and richness of the soil. Where the suppy is rather limited it is desirable to use light applications, 10 to 20 tons per acre, and supplement this with commercial fertilizers. In fact 20 to 25 tons per acre is probably as much as can be used economically for most crops under the present conditions. However, in very intensive gardening where two or more crops are grown in one year 40 to 50 tons may be used to advantage. It should be borne in mind that manure is not a balanced fertilizer and for this reason it is more economical to use a moderate application and supplement it with chemical fertilizers.

Under most conditions broadcast application is best. When coarse manure is used it is usually applied broadcast before plowing and when well-rotted manure is used it is quite generally broadcasted after plowing and thoroughly mixed with the surface soil by harrowing. A manure spreader can be used to advantage where the amount of manure used justifies the investment. The spreader saves a large amount of labor and scatters the manure more uniformly over the surface than is possible by hand spreading.

For some crops, such as cucumbers and melons, manure is often applied in drills or hills. There is some advantage in this where the soil is poor and the amount of manure is limited because it secures a greater concentration of manure in the region of the roots. Some advantage is also claimed for the drill or hill method of applying fresh manure for its heating effect on the soil, which hastens germination of seeds of cucumbers and melons and forces them into vigorous growth. It is doubtful, however, if the drill and hill method of application often pays for the extra cost of applying. Better distribution is secured by broadcasting for most crops.

Manure Economy Experiments.—Since the problem of maintaining production of vegetables with a decreased manure supply is one of the most serious ones confronting vegetable growers, several experiment stations have undertaken definite investigational work looking to the solution of this problem. The experiments of the Rhode Island Station, the Virginia Truck Experiment Station and the Ohio Experiment Station are notable examples of this type of work. In all of these experiments the substituting of green-manure crops and commercial fertilizers for a part or all of the manure, is one of the main problems studied. However, other valuable data on plant nutrition are being accumulated.

Rhode Island Experiments.—Hartwell and Crandall (66) have reported on 6 years' results, secured at the Rhode Island Station, on the substitution of fertilizers, green manure and peat for manure. They give the following description of the experiments and of the soil:

This field experiment comprises the following 3-year rotation of two cash crops each year (W); and the same rotation modified to include the crops (names in italics) which are plowed under for green manure (X, Y, Z).

Rotation	First year (1)	Second year (2)	Third year (3)
W	Cabbage—beets	Tomatoes—spinach	Lettuce—celery
X	Cabbage—*vetch* and *rye*	Tomatoes—*rape*	Oats—celery
Y	Cabbage—*rye*	Tomatoes—*sweet clover*	—celery
Z	Cabbage—*wheat*	Tomatoes—*red clover*	—celery

An annual spring application of 32 tons of stable manure alone is compared with different combinations of fertilizer chemicals used in connection with green manures, peat and smaller amounts of stable manure.

The soil is classified as Miami silt loam. It is glacial drift of granitic origin . . . The surface soil is quite retentive of moisture, and early spring operations are retarded thereby. The subsoil is gravelly and affords natural drainage . . . Prior to the beginning of this experiment, the land had been used uniformly for farm crops and was in no more than fair condition . . .

Results from plats treated alike indicate that an average difference of about 5 per cent is liable to occur in case of plats in close proximity, whereas the difference may amount to 10 per cent in plats farther removed from each other . . .

Each plat is 21 by 69.14 feet and comprises one-thirtieth of an acre. The paths between the ends and sides of the plats are 3 feet wide . . .

Before beginning the experiment, the soil was quite acid and 4.5 tons of ground limestone per acre were added at once in preparation for certain of the crops which are sensitive to acid soil conditions. To other crops, one-third or two-thirds this amount was added. By the end of the sixth year or during the first two rounds of the rotations . . . every plat, except the peat plats, had received 12 tons of ground limestone, and the soil was practically neutral.

The sour, moist peat is composted for at least over winter with 200 pounds of hydrated lime or 600 pounds of limestone per cord of the peat. This lime is in addition to the regular amount applied to the plats.

The average regular application for the first crops of rotation W has been equivalent to ¾ ton of a 4–10–2 fertilizer whereas the extra nitrogen plat received twice as much nitrogen, the extra phosphorus plat about six-tenths more phosphorus and the extra potassium plat about twice as much potassium.

The regular application for the second crops of rotation W, which receive no new application of stable manure, has been equivalent to ½ ton of a 4–7–6 fertilizer with the nitrogen more than doubled on the extra nitrogen plat, the phosphorus increased a half on the extra phosphorus plat and the potassium increased two-thirds on the extra potassium plat.

In the green-manure rotations, X, Y and Z the regular applications for the early cabbages and tomatoes have averaged 1 ton of 4.5–8–2 fertilizer with four-fifths more nitrogen, a half more phosphorus and twice as much potassium on the plats receiving extra amounts of these elements.

The green-manure crops which were growing at the same time received an equivalent of 600 pounds of a 7–9–0 fertilizer for the regular application, and an extra amount of one or another ingredient on certain plats.

The regular application for the late celery in the green-manure rotation has been equivalent to 2,500 pounds of 4.5–7–3 fertilizer with about a half more on each of the plats receiving an extra amount of an ingredient. The green-manure crops growing at the same time received a regular application equivalent to 800 pounds of 5–6–3 fertilizer.

The yields under the various treatments mentioned are given in Table III for cabbage, tomatoes and celery. The figures are the average for the 6 years 1916 to 1921 and are computed on the acre basis, considering only the marketable part of the crop.

The yields of beets, spinach and lettuce in rotation W are given in Table IV.

Hartwell and Crandall summarize the results of their work as follows:

The yields of the early crops in this rotation were larger with 16 tons of manure and the 4:10:2 fertilizer than with 32 tons of manure without the fertilizer, namely; cabbages, 14 per cent increase, tomatoes and lettuce, 25 per cent increase. A comparison of the augmented fertilizer, with the 4:10:2 shows that additional nitrogen increased cabbages 23 per cent, ripe tomatoes 7 per cent, but lettuce none. Additional phosphorus increased cabbage 9 per cent, ripe tomatoes none and lettuce 11 per cent. There was no increase due to the extra amount of potassium. The peat and fertilizer compared with the manure and standard fertilizer gave about the same yield of cabbage, a third less tomatoes, and very much less lettuce.

The late crops of this same stable manure rotation receive no fresh application of manure. The first comparison then is between the residues from the spring application of 32 tons of manure alone, and of the 16 tons supplemented with a second application of fertilizer chemicals equivalent to a half ton of 4:7:6 fertilizer.

TABLE III.—YIELDS OF CABBAGE, TOMATOES AND CELERY UNDER STABLE MANURE ROTATION (W) AND GREEN MANURE ROTATIONS (X, Y, Z)
(From R. I. *Bull.* 188) Figures rearranged by author

Rotation	Manure and fertilizer	Yields of crops per acre			
		Cabbages,‡ bbl., 80 lbs.	Tomatoes (ripe) bu. (56 lbs.)	Celery	
				Late, doz.	Weight, lbs.
W	32 tons manure	263	471	841	16,200
W	16 tons manure + chemicals*	302	594	854	16,800
W	16 tons manure + chemicals, extra N†	374	636	954	19,500
W	16 tons manure chemicals, extra P	328	589	875	17,600
W	16 tons manure + chemicals, extra K	310	511	910	18,100
W	Peat + chemicals, extra N	267	315	670	12,200
X	8 tons manure + chemicals	319	336	740	14,100
X	Chemicals	293	278	691	12,600
X	Chemicals, extra N	317	297	689	13,000
X	Chemicals, extra P	324	280	665	12,500
Y	Chemicals	305	316	680	12,500
Y	Chemicals, extra K	294	333	712	13,100
Z	Chemicals	287	364	682	12,400

* Chemicals = ¾ ton of a 4–10–2 fertilizer for early crops and ½ ton of a 4–7–6 for the late crops.

† Chemicals in green manure rotations (X, Y, Z) = 1 ton of 4.5–8–2 for early crops and 1¼ tons of a 4.5–7–5 for the celery.

‡ Average yields of cabbage in rotation W is for 5 years, 1917–1921.

TABLE IV.—ACRE YIELDS OF CROPS GROWN ONLY ON THE STABLE MANURE ROTATION (W)

Manure and fertilizer	Yields of crops per acre			
	Beets, late, bu. (50 lbs.)	Spinach, late, bu. (12 lbs.)	Lettuce, early	
			Boxes, (18 hds.)	Lbs.
32 tons manure	196	464	801	16,500
16 tons manure + chemicals*	242	518	1,001	19,000
16 tons manure + chemicals, extra N	287	646	1,009	19,000
16 tons manure + chemicals, extra P	264	575	1,121	19,900
16 tons manure + chemicals, extra K	251	626	712	15,200
Peat + chemicals, extra N	170	277	63	8,100

* Chemicals = ¾ ton of a 4–10–2 fertilizer for the early crop and ½ ton of a 4–7–6 for the late crops.

The seasons were frequently too short for the production of full crops of beets and spinach. The fertilizer and half ration of manure residues produced 23 per cent greater yield of beets and 12 per cent more spinach than only the residues from the maximum spring application of manure. There was practically no increase, however, in the case of late celery. By adding extra nitrogen to this second fertilizer, beets were increased 18 per cent, spinach 25 per cent, and celery 16 per cent. By augmenting the phosphorus the yield of each crop was increased around 10 per cent, but there was not much effect from an increase in the potassium except that the yield of spinach was increased 21 per cent. The yields from the peat plats were very inferior.

The foregoing rotation is modified to grow, for green manures, winter vetch, rye and wheat in place of late beets; and sweet clover, red clover, and rape in the autumn followed by oats in the spring, in place of late spinach and early lettuce. Tomatoes, then, have followed the first group of green manures, and celery the second group, in strict comparison with the unmodified rotation. Cabbages have followed celery on all plats.

With one exception the green-manure plats received no stable manure. The early cabbages and tomatoes have had the equivalent of a ton of 4.5: 8:2 fertilizer, and the late celery the equivalent of 2,500 pounds of 4.5:7:3 fertilizer. Only about 10 per cent increase was obtained in any case by an extra amount of any of the ingredients in the foregoing fertilizers, and usually there was no positive increase.

The green-manure plats yielded more cabbages than the plats receiving only manure, but about a fourth less tomatoes and celery. Where in one case, 8 tons of manure were added each spring to supplement the green manures and fertilizer there was a slight gain in yield.

Less organic matter has thus far been added to the plats in the green manures, than in the stable manure. Some modifications have been made in the plan for green manuring which are expected to lead to increased production, especially an interchange in the position in the rotation, of rye, and wheat with the clovers so that the latter may have more time to become established.

Ohio Experiments.—Thorne (163) has reported on 5 years' results (1915–1919) of experiments on increasing the yield of truck crops at the Washington County Experiment Farm. The soil on which these experiments are conducted is alluvial, deposited largely from over-flow of the Ohio River. Considerable gravel is found on the surface, having been brought in and deposited during floods. The area had been used for truck growing prior to the time the experimental work was started and the soil was considered "worn out."

Thorne gives the following description of the experiments:

The experiments on increasing the yield of truck crops occupy two parallel series of plats containing 1/40 acre each. Series A receives a basic treatment of ground limestone, spread over all of the land every second season, at the rate of 2 tons per acre, and a cover crop, consisting of cowpeas after sweet corn, cabbage, and tomatoes, and rye after cucumbers.

Series B receives as basic treatment a cover crop consisting of rye on part of the land and cowpeas on the remainder, excepting plat 21, which receives straw mulch.

Each series consists of four blocks of 16 plats each on which the four crops, sweet corn, cucumbers, cabbage and tomatoes are grown in rotation, each crop being grown every season in both series.

Table V gives the average yield per year for the 5-year period 1915 to 1919 in both series, A and B.

A study of table V shows that in Series A, 800 pounds of acid phosphate, 100 pounds of muriate of potash and 320 pounds of nitrate of soda produced a larger yield of sweet corn, cabbage and tomatoes than 16 tons of manure alone. With cucumbers the yields were nearly equal under the two treatments. Manure at the rate of 16 tons per acre supplemented with 400 pounds of acid phosphate did not equal the fertilizer treatment mentioned (plat 6) on sweet corn and cabbage and increased the yield only slightly on tomatoes and cucumbers. Most of the differences in yields are easily within the range of experimental error, but the comparisons are of value. Thorne (163) makes the following comments on the results of this experiment:

The average value of the crops grown on the land receiving the basic treatment of limestone and cover crops has been $218 per acre. That on the land receiving cover crops only as a basic treatment has been $188. The combination of limestone and cover crop on plats 16 and 33 has produced total yields of only $205 and $210, but these plats are on the west side of the field, where the yields run lower than on the eastern three-quarters. Compared with plats 32 and 35, receiving cover crops only, the liming of plat 33 has apparently increased the yield by $28.70, or near the same amount found by comparing the yields from the basic treatments.

In comparing manure and fertilizers in this experiment it should be borne in mind that the fertilizer applications for the most part, were very small. The highest amount of nitrogen used in the commercial fertilizer plats (plat 6) is equivalent to the amount of this element found in five tons of average manure. The highest application of potash (100 pounds KCl) in commercial fertilizer is equal to the amount usually present in 5 tons of average manure. Most vegetable growers use larger amounts of nitrogen and potash than were used on any of the plats in this experiment, and a better comparison could be made had larger amounts of commercial fertilizers been applied.

The average value per acre of the four crops grown in this experiment, the increased value due to the manure and fertilizer treatment, the cost of treatment and the net gain are given in Table VI. The cost of the treatment is based on $2.50 per ton for manure, $20 per ton for acid phosphate, $50 per ton for nitrate of soda, $50 per ton for muriate of potash and $6 per ton for ground limestone. (Cost of treatment and

TABLE V.—YIELDS OF SWEET CORN, CUCUMBERS, CABBAGE AND TOMATOES UNDER VARIOUS TREATMENTS AT WASHINGTON COUNTY (OHIO) EXPERIMENT FARM—5-YEAR AVERAGE. (Ohio *Bull.* 344)

Plat	Treatment per acre for each crop*	Yield and increase in pounds per acre									
		Sweet corn		Cucumbers		Cabbage		Tomatoes		Average	
		Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase
1	None	7,152	.....	11,414	.....	15,344	.....	12,124	.....	11,508	
2	Shed manure, 16 tons; acid phosphate, 400 pounds	7,332	387	13,788	2,935	20,948	5,545	15,898	3,676	14,491	3,136
3	Shed manure, 16 tons	7,096	357	12,132	1,839	19,968	4,507	15,616	3,296	13,703	2,500
4	None	6,532	.....	9,732	.....	15,520	.....	12,418	.....	11,050	
5	City manure, 16 tons	7,512	1,000	12,366	2,308	18,968	3,554	14,884	2,660	13,432	2,381
6	Acid phosphate, 800 pounds; mur. potash, 100 pounds; nitrate soda, 320 pounds	7,752	1,260	12,612	2,228	20,912	5,606	15,984	3,554	14,315	3,162
7	None	6,472	.....	10,710	.....	15,200	.....	11,836	.....	11,054	
8	Acid phosphate, 400 pounds; mur. potash, 50 pounds; nitrate soda, 160 pounds	7,164	653	14,130	3,173	18,684	3,772	13,316	1,503	13,323	2,275
9	Acid phosphate, 400 pounds; nitrate soda, 160 pounds	7,460	911	14,132	2,927	18,388	3,764	14,422	2,631	13,600	2,558
10	None	6,588	.....	11,452	.....	14,336	.....	11,768	.....	11,036	
11	Acid phosphate, 400 pounds	7,388	784	13,634	2,213	16,352	2,133	13,434	1,831	12,702	1,740
12	Nitrate soda, 80 pounds; sulphate ammonia, 65 pounds	6,748	128	11,782	391	15,640	1,539	11,450	11	11,405	517
13	None	6,636	.....	11,360	.....	13,984	.....	11,274	.....	10,813	
14	Nitrate soda, 160 pounds (in two applications)	6,756	43	12,118	763	15,128	1,648	10,394	−587	11,099	467
15	Nitrate soda, 160 pounds (in one application)	6,936	145	13,134	1,783	14,880	1,904	10,580	−109	11,382	931
16	None	6,868	.....	11,346	.....	12,472	.....	10,396	.....	10,270	
	None	6,791	.....	10,979	.....	14,476	.....	11,636	.....	10,970	

* All the land in this series, fertilized and unfertilized alike, is cross-dressed every second season with finely ground limestone, 2 tons per acre, and all has received a cover crop consisting of cowpeas after sweet corn, cabbage and tomatoes and rye after cucumbers.

Plat	Treatment per acre for each crop*	Yield and increase in pounds per acre									
		Sweet corn		Cucumbers		Cabbage		Tomatoes		Average	
		Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase	Yield	Increase
21	Straw mulch	6,112	592	12,390	3,556	13,696	−416	8,316	−794	10,128	734
22	Unfertilized	5,520	.....	8,834	.....	14,112	.....	9,110	.....	9,394	
23	Manure, 16 tons; acid phosphate. 400 pounds; mur. potash, 50 pounds; nitrate soda, 160 pounds	7,888	2,008	16,232	5,916	23,464	9,088	14,734	5,610	15,579	5,655
24	Manure, 16 tons	7,828	1,948	14,676	4,360	20,936	6,560	14,642	5,518	14,520	4,596
25	Manure, 16 tons; limestone, 1 ton	8,204	2,324	16,172	5,856	22,016	7,640	14,880	5,756	15,318	5,394
26	Manure, 16 tons; acid phosphate, 400 pounds; nitrate soda, 160 pounds; limestone, 1 ton	8,356	2,476	19,486	9,170	24,096	9,720	14,262	5,138	16,550	6,626
27	Manure, 16 tons	7,948	2,068	15,430	5,114	20,016	5,640	14,220	4,996	14,376	4,454
28	Manure, 16 tons; acid phosphate, 400 pounds; limestone, 1 ton	8,564	2,684	17,826	7,510	21,208	6,832	14,764	5,640	15,590	5,666
29	Unfertilized	6,240	.....	11,798	.....	14,640	.....	9,138	.....	10,454	
30	Acid phosphate, 400 pounds; mur. potash, 56 pounds; nitrate soda, 160 pounds	7,384	1,219	17,760	5,990	19,320	5,195	10,616	2,236	13,770	3,660
31	Acid phosphate, 400 pounds; mur. potash, 50 pounds; nitrate soda, 160 pounds; limestone, 1 ton	7,792	1,701	17,450	5,708	21,984	8,373	9,942	2,318	14,292	4,525
32	Unfertilized	6,016	.....	11,714	.....	13,096	.....	6,866	.....	9,423	
33	Limestone, 1 ton	6,560	732	11,532	548	16,344	3,763	7,646	699	10,520	1,435
34	Acid phosphate, 400 pounds; nitrate soda, 160 pounds; limestone, 1 ton	7,140	1,500	13,694	3,440	20,264	8,197	10,326	3,299	12,856	4,109
35	Unfertilized	5,452	.....	9,524	.....	11,552	.....	7,108	.....	8,409	
36	Acid phosphate, 400 pounds; nitrate soda, 160 pounds; limestone, 1 ton	6,460	1,008	10,598	1,074	15,536	3,984	8,966	1,858	10,390	1,981
	Average of check plats 22 and 29	5,880	.....	10,316	.....	14,376	.....	9,124	.....	9,924	
	Average of check plats 29, 32 and 35	5,903	.....	11,012	.....	13,096	.....	7,704	.....	9,429	

* Plats 22 to 28, inclusive, receive a cover crop of rye, and Plats 29 to 36, inclusive, receive a cover crop of cowpeas after each crop except cucumbers which receive the rye cover crop. The cover crops are additional to other treatments.

Table VI.—Average Annual Value of Truck Crops Washington County (Ohio) Experiment Farm: Increase Due to Treatment and Net Gain or Loss per Acre

Plat	Treatment per acre	Average value dollars	Increased value* dollars	Cost of treatment	Net gain dollars
	Soil fertility series: Basic treatment, limestone				
1	Unfertilized	230.16			
2	Shed manure, 16 tons; acid phosphate, 400 pounds	289.82	62.72	44.00	18.72
3	Shed manure, 16 tons	274.06	50.00	40.00	10.00
4	Unfertilized	221.00			
5	City manure, 16 tons	268.64	47.62	40.00	7.62
6	Acid phosphate, 800 pounds, mur. potash, 100 pounds: nitrate soda, 320 pounds	286.30	63.24	18.50	44.74
7	Unfertilized	221.08			
8	Acid phosphate, 400 pounds; mur. potash, 50 pounds; nitrate soda, 160 pounds	226.46	45.50	9.25	36.25
9	Acid phosphate, 400 pounds; nitrate soda, 160 pounds	272.00	51.16	8.00	43.16
10	Unfertilized	220.72			
11	Acid phosphate, 400 pounds	254.04	34.80	4.00	30.80
12	Nitrate of soda, 80 pounds; sulphate ammonia, 65 pounds	228.10	10.34	4.00	6.34
13	Unfertilized	216.26			
14	Nitrate of soda, 160 pounds (in two applications)	221.98	9.34	4.00	5.34
15	Nitrate of soda, 160 pounds (in one application)	227.64	18.62	4.00	14.62
16	Unfertilized	205.40			
	Average value from basic treatments only	219.10			
	Soil improvement series: Basic treatment, cover crop				
21	Straw mulch	202.56	14.68		
22	Unfertilized	187.88			
23	Manure, 16 tons; acid phosphate, 400 pounds; mur. potash, 50 pounds; nitrate soda, 160 pounds	311.58	113.10	49.25	63.85
24	Manure, 16 tons	290.40	91.92	40.00	51.92
25	Manure, 16 tons; limestone, 1 ton	306.36	107.88	46.00	61.88
26	Manure, 16 tons; acid phosphate, 400 pounds; nitrate soda, 160 pounds; limestone, 1 ton	331.00	132.52	54.00	78.52
27	Manure, 16 tons	287.56	89.08	40.00	49.08
28	Manure, 16 tons; acid phosphate, 400 pounds; limestone, 1 ton	311.80	113.32	50.00	63.32
29	Unfertilized	209.08			
30	Acid phosphate, 400 pounds; mur. potash, 50 pounds; nitrate soda, 160 pounds	275.40	73.20	9.25	63.95
31	Acid phosphate, 400 pounds, mur. potash, 50 pounds; nitrate soda, 160 pounds	285.84	90.50	15.25	75.25
32	Unfertilized	188.46			
33	Limestone, 1 ton	210.40	28.70	6.00	22.70
34	Acid phosphate, 400 pounds; nitrate soda, 160 pounds; limestone, 1 ton	257.12	82.18	14.00	68.18
35	Unfertilized	168.18			
36	Acid phosphate, 400 pounds; limestone, 1 ton	207.80	39.62	10.00	29.62
	Average value from basic treatment only	188.40			

* During the season of 1917, 1918 and 1919 sweet corn sold at average prices equivalent to 1¾, 3 and 3 cents a pound, respectively; cucumbers at 1, 2.8 and 1.8 cents; cabbage at 1.4, 4.2 and 2.9 cents and tomatoes at 3, 3.4 and 5.6 cents. Taking the total weights of the 4 crops and the total receipts from the sales the average for the period amounts to 2½ cents a pound. Allowing ½ cent a pound for marketing, the average values at the farm are computed at 2 cents a pound.

net gain recalculated by author.) The price of $2.50 per ton for manure is entirely too low considering the price market gardeners are paying at present (1922) and the cost of hauling and applying. The actual cost would probably be nearer $5 per ton than $2.50, but the latter figure was used by Thorne.

A glance at the above table will show that the highest net gain was secured from the complete fertilizer plats in the "soil fertility series." In the "soil improvements series" the net gain from 16 tons of manure plus 400 pounds of acid phosphate, 160 pounds nitrate of soda and one ton limestone, was slightly higher than that from 400 pounds of acid phosphate, 50 pounds of nitrate of soda and one ton of limestone.

CHAPTER IV

GREEN MANURES

Green-manure crops are those grown for the purpose of improving the conditions of the soil for the growth of succeeding crops. They are sometimes called soil-improving crops and cover crops, but the latter term is generally used for the crops grown for the purpose of protecting the soil during fall and winter.

Value of Green Manures.—The beneficial effects of green-manure crops were known long before it was understood in what ways they acted to increase crop production. Experiments have confirmed and explained the fact that green-manure crops favorably affect succeeding crops.

Green-manure crops may have the following effects: (1) Increase organic matter in the soil, (2) conserve soluble mineral nutrients, (3) add nitrogen in case legumes are used, (4) transfer mineral nutrients from subsoil to surface, (5) concentrate the mineral nutrients, (6) favorably affect the bacterial life in the soil, (7) increase available elements in the soil, (8) improve the condition of the subsoil.

For the vegetable growers, the use of green crops to turn under is advocated mainly for supplying humus since fertilizing elements can be purchased in the form of commercial fertilizers. The chemical composition of soils, especially with reference to the chemical elements usually needed, can be changed much more rapidly than the physical or mechanical condition. In many truck-growing centers the only available sources of humus in quantity are crops grown for this purpose and it would be impossible to maintain production without growing some soil-improving crops. With the decrease in the available manure supply from cities and with the depletion of humus in soils from cropping the use of green manures becomes more and more important. This is recognized by many gardeners and some soil-improving crop is grown by them every year although the practice is not as general as it must become. Continuous high applications of commercial fertilizers are justifiable only where the humus content is kept up by use of green-manure crops or by use of manure.

On the physical effects of green manures Piper and Pieters (116) have the following to say:

Organic matter affects both the texture and the moisture-holding capacity of soils. Heavy clays are lightened and made more porous and sandy soils are

enabled to hold moisture better. For the best growth of the roots of most crop plants both air and moisture are needed. When a stiff soil dries and becomes hard the air is excluded and the roots are likely to suffer not only from lack of moisture but from lack of air.

Clay soil containing organic matter is more friable than similar soil without organic matter. Where soil from which the organic matter had been extracted was allowed to freeze and thaw it remained compact and did not crumble. When the organic matter previously dissolved out of this soil was returned to it the soil crumbled after freezing, the same as the original soil.

Some crop plants, as alsike clover and rice, thrive in a water-soaked soil, and wheat has been successfully matured in sealed pots from which air was excluded. In general, however, experience has amply shown that most crop plants do better when the soil in which they grow is in good tilth. This condition of good tilth is facilitated by organic matter.

Not only do the higher plants grow better in a soil rich in organic matter, but the activities of the soil bacteria are largely dependent on the supply of decaying vegetable matter. These bacteria need food and air. Their food is the dead vegetable matter, which they break down and thus make available to the higher plants. Most beneficial bacteria use air, and this they find more abundantly in a soil supplied with organic matter than in stiff clays poor in organic matter. In sandy soils there is air enough, but the addition of humus helps to hold moisture and so benefits the bacteria as well as the higher plants.

It has been shown that while 100 pounds of sand can hold only 25 pounds of water and 100 pounds of clay 50 pounds, the same weight of humus or decaying organic matter will hold 190 pounds. A good physical condition of the soil, therefore, largely depends on the organic matter in the soil.

Nitrogen is conserved by growing green-manure crops on land, which might otherwise be kept bare in late summer after an early crop has been removed. Soluble nitrates in the soil are taken up by the growing manure crop and this prevents loss by drainage or by decomposition and consequent escape of free nitrogen into the air. The soluble nitrates are transferred from the soil into the crop and in this form there is little danger of loss under ordinary conditions.

Leguminous crops grown as green manure add to the amount of nitrogen in the soil owing to their ability to use atmospheric nitrogen. Green legumes add 50 to 100 pounds and more of nitrogen per acre not including the roots and stubble. The quantity of nitrogen, of course, is dependent upon the kind and the amount of crop grown.

Green plants turned under must decay before they can be used by the succeeding crop. In this decomposition of the plant tissues acids are produced, and these, acting on the soil render parts of the mineral compounds soluble. In addition to this in the growth of the green-manure crop mineral substances are used and these are made available to the succeeding crop on decomposition of the material turned under. Phosphorus and potassium derived from decayed plants are more

readily available for the next crop than are these substances when derived from the mineral soil particles.

The roots of plants, reaching the sub-soil, collect raw materials from all parts of the soil and, on decomposition of the crop in the upper layer of soil, this material is concentrated in a more limited horizon than previously.

Selection of a Green-manure Crop.—In selecting crops for green manuring purposes the following factors should be considered: (1) Adaptation of the crop to the climate, (2) adaptation to the soil, (3) amount of vegetable matter produced, (4) rapidity of growth, (5) character of root growth, (6) character of crop, legume or non-legume, (7) ease of incorporating the crop with the soil, (8) length of time available for the growth of the crop.

Since organic matter is of greatest importance under most conditions, the crop selected should usually be the one which will produce the largest amount of material in the time available. For this reason rye is the crop most commonly grown in regions where the summer growing season is short, since this crop can be sown late in the season and attain considerable growth before winter.

Legumes.—Where all of the conditions of weather, soil and cropping systems are favorable the vegetable grower would undoubtedly select one of the legumes. Such crops furnish nitrogen in addition to the humus and because of this are more valuable than non-legumes. Among the leguminous crops grown are red clover, mammoth clover, crimson clover, bur clover, sweet clover, cowpeas, soybeans, vetch and field peas.

Of the clovers, crimson clover is the one most commonly used as a soil-improving crop on vegetable soils since it thrives well on sandy and sandy loam soils. This crop does not stand severe winters, therefore, is not used much in the North. It is, however, a good catch crop since it can be grown satisfactorily between rows of vegetables. Seed of crimson clover is very often sown at the last cultivation of late vegetables. In New Jersey, Delaware, Maryland and Virginia, and in the other states having similar climate, crimson clover does well if sown in August. In cooler regions the seed should be sown in July. Fifteen to 20 pounds of seed should be sown to the acre.

Red clover and mammoth clover are sometimes used as soil-improving crops. These clovers are used mainly in the North and the seed should be sown in July or August after the removal of early vegetables. Not less than 10 to 12 pounds of seed of red clover should be sown to the acre. The crop of red or mammoth clover may be plowed under in the fall or late in the spring.

Bur clover is one of the most valuable soil-improving crops for sections of the South, but since it is mainly a winter crop it is little used by vegetable growers. In most of the commercial vegetable growing regions of

the South, vegetables are grown during the winter. Green-manure crops are produced during the summer when vegetables from the South are not in great demand.

The cowpea is the most important green-manure crop in the South, because it produces a large amount of material in a short time and thrives in nearly all sections. It requires a large amount of heat for good growth and does not succeed well in the cooler portions of the North. This crop is grown mostly after early vegetables have been removed and before starting fall and winter crops.

The varieties of cowpeas most commonly grown for manuring purposes are Whippoorwill, New Era, Iron and Wonderful. Where root knot, caused by nematodes, is serious the Iron is probably the best variety to use since this is quite resistant to this disease. The usual amount of cowpea seed sown is about 2 bushels per acre planted with a drill or sown broadcast and covered with a harrow.

The soybean thrives better on a heavier soil and in a cooler climate than the cowpea, therefore, it can be used in the North. It is grown some in the South for manuring purposes, but on poor soils it does not produce as much crop as the cowpea and the stems are coarser. The seed may be planted in rows and cultivated, or sown broadcast in the same manner as cowpeas.

Hairy vetch is grown to some extent as a soil-improving crop, or as a cover crop on sandy soils in the North. It may be sown alone, but under most conditions, it is best to sow with rye. To secure best results, seed should be sown in July or early in August at the rate of 60 to 80 pounds per acre when grown alone. When sown with rye 20 to 30 pounds of vetch seed are planted to the acre.

Non-legumes.—Of the non-legumes rye is by far the most popular green-manure crop, because it can be grown on nearly all kinds of soils and is not adversely affected by cold weather. Rye may be planted later than other green-manure crops, therefore is a valuable crop to use after the removal of late vegetables where, as in the North, no legume except vetch is of much value. Under most conditions in the North rye is the most valuable of all of the green crops grown for supplying humus to the soil. By planning the cropping system carefully practically all gardeners can grow rye as a winter cover crop. When vegetable crops are harvested in late summer, too late for producing another crop, rye should be sown immediately in order to secure a good growth before winter. This may then be turned under for early vegetables. On the other hand, if vegetables are harvested late in the fall rye may still be sown, but will not make much growth in the North until spring. In this case it is desirable to allow the rye to grow until time to plant a crop of late vegetables, such as late cabbage. It is possible, by the methods mentioned, for vegetable growers to grow rye on nearly all their land every year and still

produce a money crop on the same land. To secure a good crop of rye at least 2 bushels of seed should be used to the acre and some gardeners use 3 bushels. It is a good practice to sow some vetch seed with the rye.

When to Plow under Green-manure Crops.—The answer to this depends upon the kind of soil, the season of the year, the age of the crop, the weather conditions and the crop to follow. For early vegetables in the North the cover crop must be plowed under early in the spring if plowing has not been done in the fall. If a late crop is to follow the soil-improving crop, full growth should be allowed in order to have a large amount of material to turn under, but the older the crop the more time will be required for its decomposition. The crop should be turned under before the soil gets dry or the green material will decay very slowly and check capillary movement of soil moisture. On the other hand when a green crop is turned under in late summer or fall in the North, the cool wet weather which follows checks decomposition and production of acidity may result. The best condition for rapid decomposition of green manures, without loss of nitrogen, is abundance of moisture and heat.

CHAPTER V

COMMERCIAL FERTILIZERS

The term commercial fertilizer is used to distinguish between animal manures and other materials applied to the soil to furnish raw materials to the plant. When the term came into use manure was not considered a commercial product while the other materials used as fertilizers were commercial products hence the use of the word "commercial." A commercial fertilizer may consist of a single chemical compound, as nitrate of soda or muriate of potash, or it may consist of a mixture of several chemical compounds; or of organic materials such as bone meal, tankage, cottonseed meal, etc. Most mixed fertilizers contain compounds of nitrogen, phosphorus and potash and each of these elements may be present in more than one form. Nitrogen is often present in an organic form, such as dried blood, tankage or cottonseed meal and in an inorganic compound, such as nitrate of soda or sulphate of ammonia. All materials applied to the soil to furnish plants with raw material, except the animal manures, are called "fertilizers" or "commercial fertilizers." Lime is a fertilizer although applied mainly to correct acidity of the soil.

Importance of Commercial Fertilizers.—In vegetable growing, commercial fertilizers are very important and are increasing in use every year. This increase is due to the shortage of animal manures and to the increasing knowledge of the importance of commercial fertilizers. It is possible to grow large crops without the use of commercial fertilizers, provided manure is used in large amount, but it is doubtful if this is now economical. Manure is not a balanced fertilizer, being especially deficient in phosphorus. Manure applied in large enough quantities to furnish sufficient phosphorus for large crops would result in a waste of nitrogen. Even with manure therefore, it is usually economical to use commercial fertilizer in some form.

The greatest demand for commercial fertilizer comes as a result of inadequate supply of manure. Even market gardeners near the cities are finding it difficult to secure manure, and are supplementing it with commercial fertilizers. The truck growers located at a long distance from a source of supply of manure depend upon fertilizers almost entirely to supply nitrogen, phosphorus and potash, and on green-manure crops to supply humus.

Commercial fertilizers contain raw material in forms more available than in manure; therefore quick acting fertilizers are of value even

where manure is used in large quantities. This is especially true because of the need of a readily available source of nitrogen early in the spring before the ground warms up. It is possible to grow crops to maturity in less time by the use of commercial fertilizers than where manure alone is used. This rapid growth is very important in vegetable growing, especially for early crops and for those in which quick growth is essential to high quality. Rapid growth is especially desirable in celery, lettuce and radishes.

Advantages of Commercial Fertilizer.—Among the advantages of commercial fertilizers are: (1) They usually contain the elements in a readily available form, (2) they require less labor in hauling and applying than manure, (3) they can be secured in any quantity and with the elements in the proportion desired, (4) they are uniform in kinds and proportions of nitrogen, phosphorus and potash and are sold under guaranteed analyses so that the buyer knows what elements and the amounts of each he is getting, (5) they furnish good materials in a complete mechanical mixture, (6) they supply sulphur and calcium in addition to the three elements usually considered. With some crops and on some soils calcium and sulphur are apparently important.

Value and Use of Nitrogen.—Of the three elements commonly supplied by commercial fertilizers, nitrogen has the quickest and most pronounced effect. Nitrogen is a constituent of all proteins and these are probably the active components of protoplasm. It tends to encourage the development of the vegetative, above-ground portion of the plant and to impart a deep green color to the leaves. It increases plumpness in seeds and it governs to some extent the utilization of potash and phosphoric acid. Nitrogen tends to produce succulence, a quality of great importance in many vegetables. Of the three elements commonly used, nitrogen is more likely to be the limiting factor than either potash or phosphorus because it is lost from cultivated soils more quickly and also because it is more expensive, and therefore, less likely to be supplied in sufficient amounts.

Nitrogen in commercial fertilizers may be in the form of soluble inorganic salts, or combined as organic material. On the form to a considerable extent depends the value of the nitrogen. The soluble inorganic forms are readily available to the plant, but the organic forms must pass through various processes leading to nitrification before the nitrogen is available to the plant. The most important inorganic nitrogenous fertilizers are nitrate of soda and sulphate of ammonia, the former being used to a much greater extent than the latter. The important organic nitrogenous fertilizers are dried blood, tankage, cottonseed meal, linseed meal, dried fish and garbage tankage. Since some of the organic nitrogenous fertilizers are also used to a very large extent as feed, the nitrogen from these materials usually costs more than from the inorganic salts

For this reason and also because of the availability of the nitrogen in the inorganic salts, the latter are being more generally used by the vegetable grower.

It is important for the vegetable grower to know the source of the nitrogen in mixed fertilizer. For early spring crops nitrate of soda is more desirable than tankage or other organic material, because the nitrogen in the latter would not be available at the time the plants need it most. Many vegetable growers prefer to have the nitrogen in mixed fertilizers supplied in both inorganic and organic forms, the former for use by plants early in the season and the latter for use later. This preference is based on the belief that nitrogen applied as nitrate of soda, will be lost by leaching if the plants do not take it up almost immediately. Experimental results, however, do not bear out this belief except in very porous soils.

Value and Use of Phosphorus.—Many soils are poor in readily available phosphorus although there may be considerable quantities of phosphorus compounds in the soil. For growing vegetables on practically all soils it usually is desirable to apply fertilizers containing phosphorus. Most mixed fertilizers contain a considerable percentage of phosphoric acid because it is usually effective and also because this is usually the cheapest of the three ingredients used in complete fertilizers. Phosphorus is supposed to hasten the maturity of the plant, increase root development, especially the fibrous roots, improve the quality of the crop and increase resistance to disease. Phosphorus is thought by many to counteract the effects of over stimulation due to excess of nitrogen, but there is no reliable experimental evidence to prove this contention.

The chief sources of phosphorus used as fertilizers are phosphate rock and animal bones. The former is much the more important at the present time. The rock contains phosphorus in the form of tri-calcium phosphate, which is treated with sulphuric acid to form acid phosphate, the material commonly used by vegetable growers. The phosphorus in acid phosphate is available to the plant. Raw ground phosphate rock is used in some sections of the country for general farm crops, but is practically never used for vegetables, except when applied to the compost pile. Most of the bone fertilizer now on the market is first boiled or steamed to free it from fat and nitrogenous material. Steamed bone is more valuable than raw bone as a fertilizer, because the fat in the latter retards decomposition. The phosphorus in both raw and steamed bone is in the form of tricalcium phosphate, which is not readily available to the plant, and therefore, should not be used as a source of phosphorus for immediate results. The bone may, however, be treated with sulphuric acid and the phosphorus changed to the available form.

Value and Use of Potash.—Potash is essential to starch formation and in transference of starch from one part of the plant to another. It

is especially important in producing root crops, but is essential in growing all crops since it is a necessary component of chlorophyll. Potash may be present in large quantities in the soil without exerting a harmful effect on the crop. It should be generally used in mixed fertilizers for vegetable growing. Applications of potash are particularly important for sandy soils and muck soils, the latter being practically always poor in this element.

The main potash compounds used as fertilizers are muriate and sulphate of potash but kainit and wood ashes are also used. Muriate is the most common form used by vegetable growers, but sulphate is preferred by some and kainit is favored by some asparagus growers. Some of the preference for sulphate over muriate is not borne out by experimental data. For most crops the muriate is at least equal to the sulphate and the former is the cheaper.

Importance of Other Mineral Elements.—While the value of commercial fertilizers (including lime) is based on the nitrogen phosphorus, potassium and calcium they contain it should be borne in mind that other mineral elements are essential to plant growth. The importance of calcium is discussed in connection with lime, page 47. It is known that sulphur, magnesium and iron are essential to all green plants. Sodium, chlorine and silicon are always present but it is not known that they are essential. They may be in some cases.

Sulphur is necessary because it is essential to the formation of proteins. It cannot be replaced by any other element. This fact has been known for a long time, but until recent times it has been assumed that all soils contained sufficient sulphur to meet the needs of crop plants. However, the plant uses much more sulphur than was formerly supposed, since the methods of analysis formerly used took into consideration only the sulphur that appeared in the ash as sulphates. Improved methods of analysis show that the total sulphur present in many plants nearly equals the quantity of phosphorus in the same tissue. Recent experiments have shown that part of the beneficial effects of many fertilizers is due to the presence of sulphur in the form of sulphates. While it is true that under most conditions sufficient sulphur is present in the soil, and supplied in fertilizers to meet the needs of most crops, there is some evidence that it may be desirable to apply this element.

Recent experiments with sulphur to control the common potato scab have given promising results. The beneficial results in this case are supposed to be due to increasing acidity of the soil.

Magnesium is a constituent of the chlorophyll molecule, serving as a means of linkage between its component organic groups. When magnesium is absent from the culture medium the plants are etiolated. Magnesium seems to be necessary to fat formation, apparently having a similar relation to this that potash has to carbohydrate-formation.

It has been suggested that the large amount of magnesium in oily seeds may be related to phosphorus-translocation rather than to fat-formation.

Excess of soluble magnesium salts in the soil produces toxic effects on plants. Calcium is very efficient in counteracting the harmful effects of magnesium salts and this fact has been responsible for a large amount of study on the calcium-magnesium ratio in plants.

Iron is apparently essential to chlorophyll-formation, although it is not a constituent of the chlorophyll molecule. In the absence of iron from the culture medium a plant does not produce chlorophyll. It is not definitely known just how iron is related to chlorophyll-formation. Some authorities have suggested that it acts as a catalytic agent.

Iron is used in very small quantities by plants and all agricultural soils contain enough for crop production. Soluble ferric compounds are the source of supply of iron to plants; *ferrous* compounds being highly toxic.

Sodium is not considered as essential to growth although it is present in small quantities in the ash from practically all plants. It is known that sodium can liberate some of the other elements, and may therefore be of some indirect value when applied to the soil. Experiments have shown that in cases of insufficient potassium, sodium can perform a part of the role of the former element.

Chlorine is found in small amounts in plants, but it does not appear to be essential to growth, except possibly in the case of certain plants such as asparagus, turnips and a few others. Some authorities believe that common salt is of some value in growing asparagus due to chlorine rather than to the sodium. This belief is based on observation and some experimental evidence that muriate of potash gives better results than sulphate of potash, and that common salt does not increase the yield when applied with the former, but does increase it when applied with the latter. The evidence on this subject is not sufficient to justify positive statements.

Rate of Application of Fertilizers.—The rate of application of fertilizer depends upon the character of the soil, the previous treatment, the crop to be grown, the rotation and cropping system followed, etc. In general it is sound business policy to apply the various elements in sufficient quantities to secure maximum returns, but under some conditions increased yields from heavy applications of fertilizer over moderate amounts do not pay for the extra amount applied. The proportion of the various elements should be based on the character of the soil and the needs of the crop. Applications vary from a few hundred pounds to 1 ton or more per acre of high grade fertilizer. Some growers use 1½ tons or even more per acre, but it is doubtful if more than 1 ton is often justified. Certainly large applications are never justified for most vegetables unless the soil is in good physical condition. There is some

evidence of heavy applications of commercial fertilizers being harmful, especially where there is a lack of humus in the soil.

Time and Method of Application.—In general fertilizers for vegetables should be applied after the land is plowed but before harrowing. The harrowing mixes the fertilizer with the surface soil. Applications a few days prior to planting are considered best, under most conditions. For most crops, where medium amounts are used, there is no advantage in making more than one application since it is more expensive to apply the same amount in two applications. There is not much danger of loss due to leaching even if all the fertilizer is applied before the crop is planted. Experiments have shown as good results from a single application as from two or more if the same total amount of material is used.

Broadcast application is preferable to applying fertilizer in the drill or in hills for most crops, especially where sufficient quantity is used. For medium to large applications (above 1,000 pounds to the acre), application in the hill or drill is not safe because of danger of injury to the roots coming in contact with the fertilizer. Then, too, the roots do not confine themselves to the vicinity of the drill or hill, therefore it is not possible for all of the roots to take up the material when the fertilizer is confined to a limited area around the plants. Where small amounts of fertilizer are applied to crops planted in wide-spaced rows it may be good practice to confine the fertilizer to the drill or to a narrow strip near the row. With melons and cucumbers fertilizers are often applied in the drill for the reasons mentioned, but it is doubtful if this is the best practice where as much as 1,000 pounds per acre are used. The application of large quantities of nitrate of soda at one time may result in loss due to leaching, especially on sandy soils. It is probably good practice under these conditions to apply nitrate of soda in more than one application, the first before the crop is planted and later applications as side dressings or broadcast. Side dressing with nitrate of soda is quite common on some crops, especially when the plants have been checked in growth due to unfavorable weather conditions or other causes.

Various drills and fertilizer distributors have been placed on the market and they all are of value. There are drills to apply the fertilizer in the row, others to distribute it in a strip along the row and still others to scatter the fertilizer in a strip 8 to 10 feet wide. The last mentioned type is used for applying fertilizer to the whole area to be planted, the application being made before the land is harrowed. The grain drill is often used since it usually has a fertilizer attachment. Lime spreaders can also be used for applying fertilizers. All of these drills and distributors can be set to apply fertilizer at almost any rate desired.

Buying Fertilizers.—In buying mixed fertilizers the vegetable grower should purchase high-grade goods and insist on knowing the sources

of the nitrogen, phosphoric acid and potash. In general, in mixed fertilizers, part of the nitrogen, at least, should be in a readily available form such as nitrate of soda or sulphate of ammonia. If some organic source of nitrogen is desired dried blood, fine ground tankage, fine ground fish or cottonseed meal should be used in preference to such substances as garbage tankage, hoof-and-horn meal, ground leather, etc. Acid phosphate is a desirable carrier of phosphoric acid and muriate of potash is a favorite and cheap source of potash. Fertilizers should be bought on the basis of the percentage of the three important elements and the purchaser should insist on a guaranteed analysis. The lower the grade of the fertilizer the higher the cost of the elements nitrogen, phosphorus and potash because it costs as much to mix, bag, transport and handle a low-grade mixture as it does a high-grade one.

Home Mixing of Fertilizers.—Home mixing is increasing in popularity among vegetable growers. The advantages of home mixing are: (1) Lower cost of material, (2) lower transportation charges because of securing high-grade goods and the elimination of filler, (3) better knowledge of the kind and amount of each material used, (4) better opportunity to mix the fertilizer to suit the needs of the crops and soil, (5) educational value, for no farmer can mix his own fertilizers without becoming familiar with the carriers, their availability and their effects. These advantages do not necessarily mean that home mixing should always be practiced. It does not pay to mix at home where only a small amount of fertilizer is to be used unless it is possible to cooperate with other farmers in buying materials on a large scale.

Certain fertilizers should not be mixed due to the fact that a number of materials carry lime in the oxide, the hydrate, or the carbonate form. The lime may react on the fertilizer with which it is in contact and set free ammonia, cause reversion of acid phosphate, or produce bad physical condition. In general, nitrogenous fertilizers and soluble phosphates should not be mixed with calcium oxide, calcium hydroxide, wood ashes or basic slag. Nitrate of soda, muriate of potash and kainit should not be mixed with calcium oxide and calcium hydroxide unless the mixture is to be applied immediately.

The calculation of the amounts of the carrier and filler necessary to make up a ton of fertilizer having a certain formula is a matter of simple arithmetic. Suppose a fertilizer containing 4 per cent ammonia, 8 per cent phosphoric acid and 8 per cent potash is desired. To make the calculation simple we will use nitrate of soda containing 18 per cent ammonia, acid phosphate with 16 per cent phosphoric acid and muriate of potash containing 50 per cent of potash. The first step is to find out the amount of ammonia, phosphoric acid and potash in a ton of 4–8–8 fertilizer. This is done by multiplying the percentage by 20 as follows:

	Per cent = lb. per hundred	Pounds per ton
Ammonia	4 × 20	80
Phosphoric acid	8 × 20	160
Potash	8 × 20	160

The next step is to find how many pounds of nitrate of soda, acid phosphate and muriate of potash are required to furnish the above amounts. Since nitrate of soda contains 18 pounds of ammonia per hundred it will require as many times 100 pounds as 18 is contained in 80 or $\frac{80 \times 100}{18} = 444$, or $\frac{80}{0.18} = 444$ pounds of nitrate of soda. For phosphoric acid the calculation would be $\frac{160 \times 100}{16} = 1{,}000$ pounds of 16 per cent acid phosphate and for potash it would be $\frac{160 \times 100}{50} = 320$ pounds of muriate of potash. Adding these three amounts together we would have 1,764 pounds instead of a ton, but to make a ton 236 pounds of filler would be added. It is not necessary to use this filler as the 1,764 pounds of mixture would contain exactly the amounts of ammonia, phosphoric acid and potash in one ton of a 4–8–8 mixed fertilizer. However, where the mixture is not to be used immediately some filler which will prevent caking should be used. Most gardeners prefer part of the ammonia in mixed fertilizers to be derived from organic materials such as dried blood, tankage or cottonseed meal and where one of these is used there is no need of a filler or drier.

In mixing of fertilizers it is important to have the ingredients thoroughly mixed. This can be done by hand as follows: Pour out one of the ingredients on the floor and level off the pile, then put on the second and rake level and continue in this way until all the ingredients are on the pile. Then begin at one end and shovel the material on a sand screen set at an angle of 45 degrees to the floor. The fine material will fall through and the lumps will roll to the bottom of the screen where they can be crushed with shovels or a lump crusher. After screening the pile should be turned over twice to insure thorough mixing.

Where mixing is to be done on a large scale it is advisable to have a mechanical mixer. Power-driven mixing machines are being used by organizations which buy fertilizers cooperatively for farmers.

The Use of Lime.—It is known that many vegetables require a neutral or slightly alkaline soil for best development; others thrive on a soil that is slightly acid and are benefitted little or not at all by applications of

lime; while still others are actually reduced in yield where the acidity is completely neutralized. Hartwell and Damon (69) report results of experiments conducted by the Rhode Island Station to determine the effects of liming an acid soil on the yields of various crops. In the case of vegetables the authors attempted to state the approximate relative degree of benefit from liming. Those crops which were benefitted most are placed in group 3, and those benefitted to a lesser degree are listed in the groups 2 and 1 respectively. Those crops which are tolerant of a moderate degree of acidity, so that the addition of lime resulted in only a small increase or an actual decrease in yield, are in group 0. Regarding the reliability of the data presented, Hartwell and Damon make the following statement:

It is evident that in many cases the experimental data are too meager to allow a satisfactory classification; in a few instances, however, results from other experiments were taken into consideration in making the classification. On the other hand, sufficient data regarding certain kinds of plants have been secured at this station to enable classification into a larger number of groups than is attempted here. When the reader sees that "3" accompanies a certain crop, he may know that inattention to lime requirements is liable to mean that the crop will not be satisfactory. Even if nothing is known regarding the requirements of the soil, it is much wiser to add lime as a preparation for such crops than to attempt to grow them without doing so. Probably an unsatisfactory growth of these crops is more often attributable to a lack of basic materials, such as lime, than to any other cause.

Of course what has been said regarding crops in group "3" is applicable in a lesser degree to the crops marked "2." The crops accompanied by "1" generally made a better growth on plat 29 (limed) than upon plat 27 (unlimed) but upon a soil somewhat less acid than that of plat 27 quite satisfactory growth might be secured without liming.

It will of course be understood that the figures used to represent the degrees of benefit from liming are only relative, since the absolute amount of benefit for neutralizing purposes depends largely upon the amount of soil acidity and upon whether the lime is applied in such amounts and in such a way that the greatest possible beneficial effects are secured. Injudicious liming may result in a decreased crop under conditions where an application made properly would be beneficial. Especially where the acidity is either not large, or the crop is tolerant of the same, the effects of lime are quite variable depending upon the form of lime and the method of application.

In Table VII the crops are grouped according to their response to applications of lime as shown by the results secured by the Rhode Island Station. Instead of listing the crops in alphabetical order as given by Hartwell and Damon, the author has grouped them according to their response to lime.

Coville (31) lists turnip, radish, sweet potato and carrot as being tolerant to soil acidity. No doubt many more crops are tolerant to

Table VII.—The Effects of Liming an Acid Soil on the Growth of Different Kinds of Vegetable Plants. (Data from R. I. *Bull.* 160)

Group 0	Group 1	Group 2	Group 3
Beans, snap	Brussels sprouts	Broccoli	Asparagus
Beans, field	Carrots	Cabbage	Beets
Beans, lima	Chard	Cauliflower	Celery
Chicory	Collards	Eggplant	Leek
Corn, sweet	Cucumbers	Martynia	Lettuce
Corn, pop	Dandelion	Muskmelon	Onions
Parsley	Endive	Mustard	Parsnips
Potato	Kale		Pepper
Radish	Kohl-rabi		Salsify
Tomato	Peas		Spinach
Turnip	Pumpkin		
* Watermelon	Rhubarb		
	Squash		

* The watermelon yield was materially reduced by liming.

slight acidity, but relatively few vegetables produce good crops on very sour soil.

At the Virginia Truck Experiment Station the effect of liming has been studied with various vegetables and in Bulletin No. 4 of that station it is stated that: "Experiments on Norfolk soils show that liming is beneficial to all crops except beans, peas and tomatoes." It should be noted, however, that only a small number of vegetables was included in the experiments mentioned.

The forms of lime commonly used are ground limestone (calcium carbonate, $Ca\ CO_3$); burned lime (calcium oxide, CaO) which is made by burning the calcium carbonate, the burning setting free the CO_2; and slaked lime (calcium hydroxide, $Ca\ (OH)_2$). The slaked lime is also known as caustic lime and hydrated lime and is formed from calcium oxide and water. When burned limestone is exposed to air it takes up moisture and is gradually changed to the hydroxide form. This change is rapid if the lime is exposed to rain or if water is artificially applied. The burned lime is usually slaked before being spread on the land.

Land plaster or gypsum (calcium sulphate) is sometimes used in the place of lime, but it does not take the place of any of the forms of lime in correcting acidity. It never neutralizes acidity, but helps to make neutral soils acid. The calcium of this compound is removed from the soil leaving sulphuric acid behind to combine with some other base.

Value of Lime.—Lime is used in agriculture mainly for the purpose of neutralizing acid soils, but in doing this there are other indirect beneficial results such as promoting the decomposition of organic compounds,

providing favorable conditions for nitrification and assisting the growth of nitrogen-gathering organisms associated with leguminous plants. Lime may be of value in converting insoluble forms of potassium and phosphorus into soluble forms. On clay soils lime brings the fine particles into aggregates which are loosely cemented by calcium carbonate and the tilth of such soils is thereby improved. Sandy soils may be improved by small applications of lime as the carbonate serves to bind some of the particles together, making the structure somewhat firmer and increasing the water-holding power.

While it is often stated that lime is not a fertilizer but rather a soil amendment, it should be borne in mind that calcium is essential to growth of higher plants. This fact has been known by plant physiologists and others for a long time, but it is only within recent years that its importance as a constituent of the cell wall has been recognized. True (168) has recently (1922) given a brief review of the status of our knowledge on the significance of calcium for higher green plants. He points out that unless sufficient calcium ions are present in the culture media to unite with the pectic acid to form the calcium pectate middle lamella the cells may disintegrate. In solutions containing potassium the potassium ions unite with pectic acid to form potassium pectate which is relatively soluble in water and the cells disintegrate. Calcium ions actually diffuse out of the calcium pectate middle lamella into the solution. With magnesium solutions the pectic acid unites with magnesium ions to form magnesium pectate which apparently becomes toxic. When all of the calcium becomes replaced by magnesium the cells die. Death is probably due to the toxic action of the magnesium ions on some of the cell structures. True gives the following practical results of the studies that have been made:

It appears that a certain quantity of Ca ions must be present in the medium for the maintenance of the chemical and functional integrity of the cell wall, as well as the chemical and functional integrity of the deeper lying living parts of the cells of absorbing roots of higher green plants. When this is so maintained, absorption takes place in the manner we are accustomed to call normal. When this necessary minimal supply of Ca ions in the medium is lacking, be it in soil solution, water culture, or sand culture, the function of absorption is upset and a more or less marked leaching of ions from the plant follows. In the absence of this necessary minimum of Ca ions, the soil solution or culture solution may be rich in all other required ions, but these are useless to the plant. They are unabsorbable. This brings us face to face with a condition of affairs in plant nutrition that has not been recognized and therefore has not been characterized. We may fairly say that Ca ions make physiologically available other equally indispensable nutrient ions. The practical consequences that follow from this way of looking at the fertilizer problem have not thus far been realized. We learn why from earliest times civilizations have grown up on soils rich in limestone debris. We learn why agriculture has readily succeeded in some regions, not in others. We

understand why, by the use of lime, lands have been rendered capable of supporting largely increased populations. We are now able to correlate these broad facts with those of cell physiology and to suggest perhaps not the calcium function sought by Jost, but one way perhaps of many in which higher green plants find calcium necessary.

From what has been said regarding the importance of calcium it might be inferred that applications of lime or some other calcium compound to the soil is always necessary. This, however, is not the case since many soils contain enough calcium to meet the needs of crop plants. In most mixed fertilizers and in various phosphates calcium is present in combination with phosphorus, and it is probable that this would meet the needs as far as nutrition of the plant is concerned.

Amount and Time of Application.—The amount of lime to supply depends upon three factors: (1) The character of the soil, (2) the kind of crops grown and (3) the form of lime used. On very sour soils the application may be as heavy as 3,000 or 4,000 pounds of quicklime to an acre but it is usually better to make lighter applications more frequently. Heavy soils, containing considerable organic matter can utilize large amounts of calcium compounds more fully and with less danger of injury than light soils, poor in organic matter. On light soils the application should generally not exceed 2,000 pounds in one year and 1,000 to 1,500 pounds would probably be safer.

It has already been pointed out that some crops require lime while others are injured if it is present in large amounts in the soil. However, calcium carbonate may be applied in much larger amounts than quicklime or slaked lime without risk of injuring the crops. In applying lime it should be kept in mind that the constituent of value is calcium and the amount of the compound to use should be based on the proportion of calcium to the other elements. Assuming that the different forms are of equal purity to find out how much slaked lime is equal to a given amount of quicklime multiply the number of pounds of quicklime by 1.3; to find out how much calcium carbonate is equal to a given amount of quicklime multiply the latter by 1.8.

Lime is commonly applied in the spring, but it may be applied at any other convenient time. It is never well to lime more than once in a year and on many soils it is not necessary more than once in 3 to 5 years. The lime should be evenly distributed and, if applied to the surface, it should be mixed with the soil by harrowing.

Ground limestone and slaked lime are generally applied with a drill or lime distributor, while quicklime is often put in piles and allowed to slake after which it is spread with shovels.

CHAPTER VI

SEEDS AND SEED GROWING

Good seed is very essential to successful vegetable growing. The most careful gardener cannot achieve success with poor seed, even if he gives the greatest attention to all other factors of production. Since the cost of seed is a small item in the total cost of production of most vegetables the very best obtainable seed should be secured. Seed to be classed as good must meet the following requirements: (1) Must be viable, (2) must be free from weed seeds and foreign matter, (3) must be true to name and not mixed, (4) must be free from diseases and (5) must produce a good type of product for the variety in question.

Buying Seeds.—It is usually desirable to buy the best seed procurable making the cost a secondary consideration. Cheap seed is usually the most expensive in the long run. The vegetable grower should secure all the information possible on reliable sources of seed of the strains and varieties of crops he grows. After getting this information he should determine for himself on his own land the strains that produce the best results. Strain tests conducted at various experiment stations have shown great variations in yield, earliness, uniformity and other important qualities, even within a variety. This is true for practically all varieties of all the important vegetable crops, hence it is important to locate the superior strains and then stick to them until some better ones are found.

Growers should buy only from reliable dealers for such firms understand that it is good business to satisfy their customers. All reliable seed houses make a specialty of some crop or crops, and very often the seedsman who gives special attention to a particular crop develops and maintains superior strains. It usually pays to buy from seedsmen who take pride in certain crops. In other words, the up-to-date gardener may buy seed of tomato from one firm, of cabbage from another, of sweet corn from still another, etc.

Novelties.—While the commercial gardener should make his main plantings of tested and reliable strains and varieties it is desirable to try new and promising kinds. It is by testing new, or so called new varieties and strains that the best is discovered, but the grower who depends upon the highly advertised novelties for his commercial plantings usually fails. Try the new while making a living from the old reliable kinds. The grower producing only a few crops can well

afford to try the novelties, for now and then he will find something of distinct merit.

Longevity of Vegetable Seeds.—It is well known that seeds of some vegetables retain their vitality longer than seeds of others. Seeds of pumpkins and squashes, for example, live longer than seeds of carrots, onions and parsnips. It is also known that any kind of seed retains its vitality longer under some condition than under others. Duvel (42) has reported results of germination tests of sweet corn, onion, cabbage, radish, carrot, pea, bean, watermelon and lettuce seeds stored in various sections of the United States. A comparison of the germination of the seeds stored at Ann Arbor, Michigan, and Mobile, Alabama, will serve to illustrate the effect of climate on vitality of seeds. After the seeds had been stored for 128 days germination tests were made. The percentage germination was much higher at Ann Arbor, Michigan, than at Mobile, Alabama, with the exception of tomato and watermelon. A second test was made in 251 days and the difference was still greater. Table VIII gives the percentage germination of the various seeds after being stored 128 and 251 days.

Table VIII.—Effect of Climate on Vitality as Shown by Percentage of Germination
(Adapted from B. P. I. *Bull.* 58)

Kind of seed	Stored at Ann Arbor, Michigan		Stored at Mobile, Alabama	
	Number of days		Number of days	
	1280	2510	1280	2510
Sweet corn "A"	100.0	98.0	80.0	20.0
Sweet corn "B"	92.0	80.0	48.0	12.0
Onion	95.0	97.5	7.0	0.0
Cabbage	96.0	91.0	64.5	17.0
Radish	82.5	77.5	58.5	51.0
Carrot	76.0	86.0	59.0	8.5
Pea	90.0	98.0	69.2	44.0
Bean	98.0	100.0	58.0	0.0
Tomato	89.0	98.0	90.0	79.5
Watermelon	100.0	96.0	98.0	64.0
Lettuce	82.0	92.5	63.0	20.0

The low vitality of the seeds stored at Mobile, Alabama, was attributed to high humidity. Duvel (42) shows that there was a close relationship between the rainfall and the loss in vitality of the seeds. The loss was directly proportional to the amount of rainfall. He states that the deterioration is more apparent as the temperature increases, but the injury due to the increase in temperature is dependent on the amount of

moisture present. Table IX shows the relation of rainfall and temperature to loss in vitality of 13 different samples of seeds.

TABLE IX.—RATIO BETWEEN VITALITY, PRECIPITATION AND TEMPERATURE
(Table VII B. P. I. *Bull.* 58)

Place where seeds were stored	Average loss in vitality 13 samples, per cent	Annual precipitation inches	Temperature	
			Mean F	Maximum F
Mobile, Ala	71.98	91.18	71.4	96
Baton Rouge, La	41.39	66.37	72.2	98
Durham, N. H	39.58	48.20	52.3	98
Auburn, Ala	33.91	62.61	64.4	98
Lake City, Fla	29.38	49.76	73.3	103
Wagoner, Ind	28.41	42.40	67.1	107
Ann Arbor, Mich	2.52	28.58	49.12	98

The mean temperatures given in the above table are not the mean annual temperatures, but the averages covering the time during which the seeds were stored. From the table it will be seen that the rainfall is a factor of much greater importance than temperature. Duvel explains the apparent discrepancy for Durham, N. H., by the fact that the samples were stored in a hall which opened directly into a chemical laboratory. He suggests that the low vitality of the seeds might have been due to injury by gases from the laboratory.

TABLE X.—LENGTH OF TIME SEEDS MAY BE EXPECTED TO RETAIN THEIR VITALITY WHEN PROPERLY HANDLED

Kind of vegetable	Years	Kind of vegetable	Years
Asparagus	3	Parsley	1
Bean	3	Parsnip	1
Beet	4	Peas	2
Cabbage	4	Pepper	2
Carrot	2	Pumpkin	4
Cauliflower	4	Radish	4
Celery	3	Salsify	1
Cucumber	5	Spinach	4
Eggplant	5	Squash	4
Kale	4	Sweet corn	2
Lettuce	5	Tomato	3
Muskmelon	5	Turnip	4
Okra	3	Watermelon	5
Onion	2		

Experiments by Duvel in storing seeds in open and sealed bottles and in packages with definite quantities of moisture and at various known temperatures have shown a very close relationship between loss in vitality and the increase in water content, the deterioration increasing also with the temperature.

Seeds to keep well in storage must be mature, thoroughly cured and stored in a dry place. The temperature under most conditions is not an important factor if the moisture content is kept very low.

Since the length of life of seeds depends upon the kind of vegetables and conditions under which the seeds are grown, cured and stored, the figures given in Table X are only approximate.

In considering the figures, in Table X it should be kept in mind that there is no way of knowing the condition under which the seeds have been handled, nor how old they are when secured from the dealer. Some seedsmen make a practice of holding certain seeds one year for the purpose of testing for trueness to type so that such seeds are two years old when put on the market. In addition to this, many seedsmen put out old seeds that have been left over, especially of the kinds which retain their vitality for several years. The only sure way to determine the vitality of seeds is to make a germination test.

Seed Testing.—The term "seed testing" is usually used in connection with purity and viability. Since vegetable seeds are fairly free from impurities, testing for purity is not of much value, but testing for viability or germinating qualities is important, for such a test may be the means of avoiding losses due to sowing seed of low germinating power. By making a germination test the gardener knows how much seed to plant to get a good stand and may save time by avoiding the necessity of replanting. Seed kept over from one year to the next should always be tested for germination before planting, because some seeds completely lose their viability in one year and many others lose considerably in vitality and produce weak plants. A simple method of making a germination test is to count out 25, 50 or 100 seeds of the sample to be tested and to place these between folds of moist blotting paper or moist cloth (cotton flannel). The blotting paper or cloth is placed in a soup plate and another plate is inverted over the lower one to prevent rapid drying. The seeds should be placed in a warm room and kept moist, but not wet, by sprinkling the blotting paper or cloth with water. As the seeds sprout they are counted and thrown away. The rapidity of germination and the vigor of the sprout should be noted, for seeds which germinate very slowly and produce weak sprouts may fail to produce plants when planted outside.

Variety and Strain Testing.—Testing for trueness to type is more important than testing for purity and germination since there is little loss from impurities or low germination. Most vegetable seeds are clean and have a fair germination, but very often the crop produced

is not true to type. It is not uncommon to find fields of Golden Self-blanching celery with a large percentage of off-type green stalks. Ten to 15 per cent off-type plants is not exceptional and sometimes it is much higher. In fact, the writer has seen whole plantings, of several acres in extent, turn out to be large green celery instead of Golden Self-blanching which the grower thought he was getting. Many celery growers are now testing all of their seeds a year in advance and are avoiding the losses due to poor strains, mixed seed, etc. The cost of celery seed is a very small item compared to the cost of planting and growing the crop so that it pays to be sure of the strain before planting on a large scale. Some of the large associations arrange with seed dealers to furnish samples of seed in advance so that the lots may be tested without purchasing the whole amount needed for the following year. The seed giving the best results is purchased and the other lots are released. Many reliable seedsmen are willing to do this because they retain their large customers and also get a good price for the seed which has proved satisfactory. Cabbage, cauliflower and other seeds may be and are sometimes tested in the same way. Testing for trueness to type is more important for those crops grown from seed started in seed beds and transplanted than for crops whose seeds are planted in place because the seeds of the former represent such a small part of the cost of the crop.

Great differences in yield and other characters exist between strains of the same variety and it is only by trial that the superior strains are found. Myers (119) has reported tests on 29 strains of Jersey Wakefield cabbage covering a period of 3 years and on 24 strains of Charleston Wakefield for the same period. In the former the lowest yielding strain produced 6.93 tons and the highest 10.76 tons to the acre. There was a still greater variation in earliness; the earliest strain producing 2.88 tons and the latest 0.22 tons per acre at the first cutting. The average weight per head varied from 1.09 to 1.69 pounds. With Charleston Wakefield the highest average yield was 11.53 tons and the lowest 8.07 tons per acre. The yield at the first cutting varied from 1.79 to 6.46 tons per acre and the average weight per head varied from 1.57 to 1.92 pounds. Similar results are reported for midseason and late varieties of cabbage.

Zimmerley (189) has recently (1922) reported results of 2 years' experiments with Jersey Wakefield and Charleston Wakefield at Norfolk, Virginia. These show similar variations to those reported by Myers. The average total yield of Early Jersey Wakefield per acre varied from 6.54 to 9.87 tons, while the average of all strains was 8.56 tons. In earliness there was a greater variation, the latest strain producing only 0.9 of a ton per acre at the early harvest while the earliest strain produced 5.43 tons at the same time. The average total yield of these two strains was practically the same. With Charleston Wakefield the lowest total

yield was 10.60 and the highest 14.22 tons per acre. The lowest yield at early harvest was 0.4 and the highest 3.50 tons per acre.

Strain tests have been made with many other vegetables and they show similar results to those given for cabbage.

Relation of Size of Seed to Crop Yield.—Many experiments have been conducted during the past 30 to 40 years to determine the effects on the yield of crops of the size of seeds planted. Many of these experiments dealt with field seeds, but some of the investigators worked with vegetable seeds. In general, it may be said that experimental results have shown an advantage in favor of large seeds. The most complete study of this question that has come to the author's attention is that reported from the Vermont Station by Cummings (35). He worked with sweet peas, sweet pumpkin, Hubbard squash, lettuce, beans, parsley, radish, spinach and peas. A summary of the results of this study will suffice to show the importance of eliminating the small seed.

Experiments with sweet pumpkin showed an advantage in earliness from the large seed. Seventy-six plants grown from large seeds produced 65 more ripe fruits and 310 pounds more edible product than the same number of plants from small seeds. The plants from large seeds averaged $1\frac{3}{4}$ ripe fruit per vine or $9\frac{1}{6}$ pounds, while the plants from small seeds averaged less than one ripe fruit or a trifle over 5 pounds. The plants from small seeds produced a greater number of fruits but they were green at the normal time of harvest.

With Hubbard squash the large seed produced larger fruits but no greater number. Seventy-five plants grown from large seed produced 166 pounds more salable squash than the same number of plants from small seed. "The higher yielding capacity of large seed is not due to earlier germination, for the plants were nearly uniform in this respect. The seedlings derived from large seed were more stocky and hence it may be assumed that the production gain is attributed to the greater size of the embryos. A stronger growth force and greater vitality is therefore ascribed to plants which are grown from large seed."

Five varieties of lettuce were used in these experiments, namely Hittinger's Belmont Forcing, Boston Forcing, Hanson, Deacon and Iceberg. The large seed produced a greater total weight of plants, a larger percentage of heads and greater uniformity at edible maturity, than small seed. The author states that in every instance and at almost every stage of growth it could be seen that the plants grown from large seed were much more uniform in stature and in time and manner cf heading.

Experiments with beans extended over three seasons and attention was directed chiefly to earliness, yield and the relative importance of size and of past productivity. In comparison with medium sized seed, large seed produced an early crop and small seed a late crop. In com-

paring past productivity with present size the author states that it appeared that the basis of selection influences the yield, that heredity is probably of more importance than size and that neither heredity nor size can be reckoned with alone without recognizing the influence of the other factor. The amount of production either of full or empty pods shows that there is much advantage in the use of large seed; and this holds whether string beans or seed beans are considered.

Parsley plants from large seed produced larger leaves, more leaves per plant and continued to be more vigorous even after two cuttings have been made.

Two varieties of radishes, French Breakfast and Early Scarlet Globe, were used and sixteen different trials were made. The weight of the edible portion of the plants was approximately 50 per cent greater from large than from small seed. The viability of large seed was much better than of small seed, and the radishes from large seed reached edible maturity earlier than those grown from small seed.

Large seed regardless of its source, of mixed or unmixed heritage is superior to small seed of the same source, because it gives larger plants, greater uniformity of stand at edible maturity, and a maturation gain of 7 to 10 days. In actual practice this advantage may be secured by sifting out and discarding the small seed.

Seven tests were made with spinach, Victoria and Long Standing. The plants grown from large seed were earlier, heavier, and more leafy, than those grown from small seed. The total yield from large seed was 14 per cent greater than from small seed.

Seed Growing.—Seed growing is a highly specialized business requiring particular knowledge and skill; therefore, most gardeners should purchase their seeds through the regular channels. Seeds of many crops are grown commercially in regions where the soil and climatic conditions are favorable and some are produced largely in foreign countries where labor costs are much lower than in the United States. Some crops, such as cabbage, cauliflower and peas thrive best in a cool climate, while others such as watermelons grow best in a warm climate. California is an important seed-growing state because the climatic conditions for curing and handling seeds are almost ideal. In humid regions there is danger of loss at harvest time due to rains, hence a dry region is preferable, other things being equal.

While most gardeners should purchase a large part of their seeds, there are many progressive men who are growing all of their seeds of certain crops, and finding it especially profitable. The growing of seed at home may be profitable because of high quality crop produced by carefully grown seed. It is doubtful if the gardener can produce seed as cheaply as the commercial seed grower, but he should be able to produce seed

better adapted to his conditions. Before undertaking to grow seeds the gardener should know what he wants and how to go about getting it. He should have thoroughly fixed in mind the type of plant or plant product he wishes and then should know the methods to use to secure his ideal. For most gardeners simple selection for the desired characters should be followed. The grower should also know how to grow and handle seed of the kinds he wishes to produce. At first he should attempt to grow only those requiring the least expert knowledge of seed growing. Crossing and hybridization are too complicated for anyone but a specialist.

In seed growing one of the serious problems is to isolate the seed plats so that there is no danger of cross-pollination. Some crops are normally cross-pollinated while others are normally self-pollinated. With the latter class it is fairly safe to plant different varieties together without danger of crossing while with the former class it is not safe to plant two varieties near together and in some cases it is not safe to plant closely related species near together.

The following crops are normally self-pollinated and different varieties may be planted together with little danger of crossing:

Beans, lettuce, peas, lima beans, tomatoes.

The blossoms of the following crops are normally cross-pollinated and varieties and closely related species should be segregated:

Beets.
Cabbage (crosses readily with cauliflower, kale, rape, etc. if blossoming at same time).
Cauliflower (crosses with cabbage, etc.).
Kale (crosses with closely related species).
Kohl-rabi (crosses with closely related species).
Turnips (cross with closely related species).
Radish (crosses readily with wild radish).
Carrot (crosses readily with wild carrot).
Corn, sweet (crosses readily with field corn).
Cucumbers (cross with gherkins, but not with muskmelons, watermelons, or squashes).
Muskmelon (does not cross with melons, pumpkins or squashes).
Pumpkins (cross with pumpkins and squashes belonging to same species).
Watermelon (crosses with citron melon but not with other curcurbits).
Parsnip (crosses with wild parsnip).
Spinach.
Salsify.
Okra.

In growing seeds of crops that are readily cross-pollinated and cross with closely related plants it is necessary to have considerable land if seed of several varieties is to be grown. The distances necessary to separate varieties depend upon the crop and method of pollination. Wind-blown pollen from corn may be carried considerable distances.

Another serious problem confronting the seed grower in many regions is the holding over of the plants saved for seed. This is true of biennial crops, especially cabbage, cauliflower, Brussels sprouts and celery. Holding such crops as beets, carrots, parsnips and turnips from harvest time in the fall until time for planting in the spring is not a simple proposition, and, in most regions is accompanied by considerable expense and some loss. The beginner would do well to start with annuals, especially such crops as tomatoes, beans, peas, sweet corn, melons, squashes, pumpkins and others easily grown. He should not attempt to grow seeds where the climatic conditions are very unfavorable to production, harvesting and curing, nor should he attempt to grow seed of more than one variety of any crop which readily crosses unless sufficient land is available to isolate the plantings.

Since seed growing is a special subject it is not within the scope of this book to do more than point out a few factors that should be considered before undertaking the work. Those interested in seed-growing methods are referred to special books and bulletins covering the subject.

CHAPTER VII

GREENHOUSES, HOTBEDS AND COLD FRAMES

GREENHOUSES

Since greenhouse construction and management are subjects of special courses in most agricultural colleges they are discussed here only from the standpoint of use by the market gardener as an adjunct to his outdoor gardening. Most up-to-date market gardeners in the North have at least a small greenhouse to start plants during the winter and early spring and many have large ranges for growing crops to maturity during the forcing season. Market gardeners have entered the forcing business by utilizing the greenhouses for growing crops to maturity when the space is not needed for starting plants.

Advantages of Greenhouses.—For the market gardener and the truck grower in the North the greenhouse is far superior for starting plants to the hotbed or the cold frame. Some of the advantages are: (1) The temperature can be more easily controlled in greenhouses than in other forcing structures, (2) the ventilation can be regulated much better and there is much less danger of chilling the plants, (3) the facilities for work are more convenient in a greenhouse than in hotbeds, (4) the plants can be watered and otherwise cared for better and at less expense in greenhouses than in hotbeds and cold frames. During early spring there is danger of chilling plants in hotbeds when the sash is removed for watering, transplanting, etc. There is no such danger in greenhouses. The use of greenhouses for growing crops to maturity has many advantages for the market gardener. These advantages are: (1) Enabling the grower to keep in touch with the market during the whole year, (2) providing employment for the regular help during the winter and (3) utilizing the grower's time to good advantage and adding to his income. The demand for fresh vegetables during the winter has increased very rapidly within recent years and is still on the increase. This is especially true of lettuce, tomatoes and cucumbers. As people learn more and more the value of vegetables in the diet, the demand for fresh vegetables increases and for this reason the vegetable forcing industry may be expected to continue to grow. Market gardeners are likely to engage in the forcing industry to keep up with the demand.

HOTBEDS

Use of Hotbeds.—The main use for hotbeds is for starting plants to be grown in the garden or field, although they are used to a considerable

extent to grow crops to maturity out of the normal growing season. Before greenhouses came into such general use, nearly all market gardeners depended upon hotbeds for starting plants such as cabbage, tomatoes, eggplants, peppers, etc. Even where they have greenhouses most gardeners still use hotbeds. Practically all market gardeners in the North, who do not have greenhouses for starting plants during winter or early spring, use hotbeds for this purpose. Hotbeds are also used in many sections of the South for starting plants as well as for growing crops, such as lettuce and radishes, to maturity.

Location.—The main considerations in locating hotbeds are: (1) Nearness to the farm buildings so that they can be cared for with the least trouble; (2) proximity to a good water supply; (3) protection from the cold winds by locating them on the south or southeast side of a hill, on the protected side of buildings, or by means of windbreaks, board fences or walls. Where no suitable protection is already available a tight fence about 5 feet high is often constructed on the north and west sides of the frames.

Southern or southeastern exposures are preferable because beds will secure more sunshine with these exposures than with others. Where there is more than one row of frames they should be parallel to each other, with ample spaces between the rows for the handling of the sashes and mats. Eight to ten feet space between the rows of frames is desirable, if the land is not too valuable.

The Hotbed Pit.—Most hotbeds are heated by the fermentation of horse manure in pits made for the purpose. The pit should be well drained so that water will not collect in it and prevent fermentation of the manure. The pit should be about the same width as the frame, which is usually 6 feet, although it will sometimes carry two rows of hotbed sash sloping in opposite directions. The depth of the pit depends upon the length of time the bed is to be used, the longer the period the deeper the pit should be because more manure is needed for a hotbed to be used for three months than one used only for one or two months. Most pits are 24 to 36 inches deep. In the North more manure is used than in the South. For starting tomatoes, eggplants and peppers more manure is needed than for cabbage, lettuce and celery, because the latter crops do not require as high temperatures as the former. As a rule 18 to 36 inches of manure is used in hotbed pits in the North while a depth of 12 to 18 inches is sufficient for starting plants in many sections of the South.

The Hotbed Frame.—The frame may be made of wood, cement, brick or stone, the first two materials being the most common. Where wood is used in making a permanent hotbed 2 by 4-inch lumber is used for posts. These posts are driven into the ground at the corners of the bed and at intervals of 4 to 6 feet along the sides of the bed. Boards or planks are nailed to these posts. It is desirable to use a double layer of 1-inch

boards or one layer of 2-inch planks for the frame. The frame may or may not extend to the bottom of the pit, but in any case it should extend 12 to 18 inches above the surface of the ground on the back side (usually north side) and 6 to 12 inches on the front, thus affording a slope preferably to the south. Every 3 feet a crossbar or slide should be placed for the sash to rest upon. For these crossbars, 2 by 3-inch pieces are satisfactory. A ½-inch strip nailed in the center of these crossbars to prevent binding of the sash is an advantage. In all permanent hotbeds durable wood should be used. Cedar, locust or chestnut for the posts and cypress or chestnut for the frame are satisfactory.

Concrete is being used by many gardeners for hotbed frames. This is much more durable than wood and is cheaper in the long run. In making frames of concrete the mixture is poured into forms in the usual way.

Sash.—Only the most durable wood should be used in making hotbed sash. Cypress and cedar are popular for this purpose. Sashes differ in size, but the most common size is 3 by 6 feet. A larger sash is too heavy to handle and is more subject to breakage. Most gardeners buy the sash already made, and this practice is usually wise, although it is advisable to inquire into the type of construction and the wood used.

The sash should be painted before being glazed. A good grade of glass is always desirable, although cheaper grades are sometimes used. The glass is generally lapped about ⅛ inch. Some gardeners prefer to butt the glass, but if the ends do not fit closely there will be considerable leakage. Each 3 by 6-foot sash is usually made for three rows of 10 by 12-inch glass, requiring 18 panes for each sash. The glass is fastened by glazing points, and then putty or mastica or some similar substance is applied along the edges of the glass against the sash-bars. These materials prevent water from running down under the glass. After glazing, the sash should be painted again. Each year a coat of paint should be given to protect them against decay.

Double glass sashes are sometimes used and they possess some advantages although the disadvantages more than offset the advantages in the judgment of most gardeners. Some of the advantages are: (1) Plants are protected almost as much where double-glass sash is used as with the ordinary sash covered with mats, (2) less labor is required in managing the frames because mats are not used with the double-glazed sash, (3) the temperature is raised more quickly in the morning and is maintained longer unless there is little or no sunshine. The disadvantages are: (1) Double glazed sash is heavier to handle, (2) it costs about one-third more, (3) the amount of light reaching the plants is less because of two layers of glass and the accumulation of dirt and moisture between the layers. It is also thought that moisture retained between the layers of glass will hasten decay of the wood.

Manure-heated Hotbeds.—Fresh horse manure is used for heating hotbeds to quite a large extent, although steam, hot-water and hot-air are also used. The manure must be fairly fresh or very little heat will be generated. Two parts excrement to one part straw or other litter will give good results. Manure with shavings as litter is not satisfactory.

Preparation of manure for the hotbed should begin 10 days to 2 weeks before the beds are to be needed. If fresh manure from the stable is used it should be placed in a flat pile about 4 feet high, 4 to 5 feet wide and any length desired. If dry at the time of piling the manure should be moistened in order to start fermentation. In 2 or 3 days the manure will begin to steam. When fermentation is well under way the pile should be turned to insure uniform heating throughout. In turning the manure that from the interior of the pile should be placed on the exterior of the new pile. In 2 or 3 days after turning the manure should be in condition for placing in the pit.

In filling the pit the manure should be thrown in layers of 5 or 6 inches and each layer trampled fairly well, especially along the sides and ends of the pit. The manure will settle several inches and allowance should be made for this. Sometimes a layer of 3 or 4 inches of straw is put over the manure in order to have a more even distribution of heat and prevent "hot spots" in the soil. A layer of 4 to 6 inches of good soil is put on the manure or straw, although 2 inches of soil is sufficient if the seeds are sown in flats instead of in the soil of the bed.

Temporary hotbeds are made by placing the frames on the top of a pile of fermenting manure. The frames are usually banked with manure as protection from cold. More manure is required where the frame is set on the pile, because the pile must be considerably wider and longer than the frame. This type of hotbed is desirable where drainage is poor.

Flue-heated Beds.—Hotbeds are often heated by flues leading from a furnace. This system is used to a considerable extent for heating sweet-potato plant beds in some of the northern sections of the sweet potato belt, and is also used for other plants. This method of heating is considered more economical than manure.

The flue-heated bed is usually 6 or 12 feet wide and of the length desired. The side walls of a permanent bed are usually made of concrete, stone or brick, but wood is sometimes used. A home-made brick furnace may be constructed in a pit at one end and below the level of the bottom of the bed. The furnace should be so located that it can be fired from the outside. The smoke and hot air are carried through a line of flue tiles, or pipes 6 inches or more in diameter, placed under the bed, and pass out through a chimney at the farther end of the bed. The line of tile or pipe should not be horizontal but slope gradually upward from the furnace to the chimney. This rise should be about 1 foot in every 25 feet of

run. The floor of the bed is usually made of boards placed on timbers laid across the bed. The pipe or flue should occupy a free space or pit beneath the bed. Whenever the flue is near the floor or is likely to get very hot it should be covered with asbestos cloth to protect the bed against fire. Either coal or wood may be used as fuel.

Heating with Steam and Hot Water.—Both steam and hot-water heating systems are being used at the present time for heating hotbeds. Where gardeners have hot-water or steam heating systems for greenhouses or other structures the frames are often heated by the same system. The temperature can be controlled better with hot water or steam than by either of the other methods, since the amount of heat can be increased or decreased as conditions warrant, merely by turning the valves in the pipes.

The heating pipes usually 2 to 4 in number are commonly placed on supports in the hotbed pit, the pipes running the length of the bed. The floor of the bed is as a rule placed 6 to 12 inches above the lines of heating pipes. Sometimes a line of pipe is run around the frame on the inside just beneath the glass, or in case of a double width hotbed, beneath the ridge in the center and around the sides. Pipes placed above the plants in this way are used mainly to protect against frost in early spring.

Hotbed Covers.—The ordinary hotbed covered with sash needs some protection during cold weather. It is necessary to cover the beds every cold night and sometimes during the entire day in early spring, especially for tender plants, such as tomatoes, eggplant, peppers, melons, etc. Old matting, carpets or heavy burlap may be used, but most gardeners use straw mats. These mats are sold by dealers in garden supplies but they may be made at home.

COLD FRAMES

Use of Cold Frames.—There are four general purposes for which cold frames are used: (1) For starting plants in the spring; (2) for hardening off plants which have been started in the hotbed or greenhouse; (3) for wintering hardy plants started in the fall; (4) for growing crops such as lettuce, radishes, beets and parsley to maturity. In many sections, especially in the South, nearly all kinds of plants are started in cold frames but they are not as satisfactory as hotbeds for most crops, where earliness is an important factor. If only a little protection is necessary, cold frames are satisfactory for starting plants. In the vicinity of Norfolk, Va., and elsewhere in the South, some crops such as cucumbers, melons and beets are started in cold frames and when weather conditions permit the frames are removed and the crops receive field culture. In this case the crops are planted in rows about the same as for general field culture. In the North cold frames are used mainly for hardening off plants which have been started in hotbeds and greenhouses.

Cold frames are constructed in very much the same way as hotbeds except that no pit is required. In fact the main difference between a hotbed and a cold frame is the absence of any form of heat in the latter, except that provided by the sun. Permanent cold frames are commonly made of concrete, Fig. 1, while temporary ones are made of boards.

Cold frames are covered with glass sash, canvas or cloth. In the North glass is mostly used, while in the South canvas or cloth is commonly used. Where sash is used the frames are as a rule 6 feet wide, although frames 12 feet wide are not uncommon. When cloth is used the beds are very often 12 feet wide.

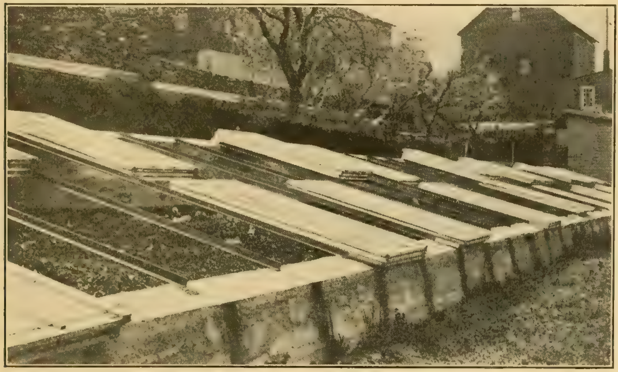

Fig. 1.—A good type of permanent cold frame.

In North Carolina and in other sections of the South, where cloth-covered frames are used for growing lettuce and other crops to maturity the sides and ends of the beds are made of 1 by 12-inch boards. The beds are 12 to 14 feet wide and of any length desired, sometimes as much as 100 yards. The boards are held in place by stakes driven into the ground. Stakes for supporting the cross strips are driven in the center of the bed about 4 feet apart making a row the length of the bed. These stakes extend above the surface of the ground about 18 inches so that when the cross strips are nailed to them and to the sides of the frame there is a fall of about 6 inches from the center to the sides. Unbleached muslin is used for covering these frames. Most of these frames are removed each year and the land plowed and harrowed before setting up the frames for the next crop.

Plant Forcers.—There are various kinds of plant forcers for individual hills or individual plants in use to some extent in this country, but this method of forcing plants has not met favor here as it has in Europe.

One of the types used in this country is a square box with a sloping top covered with a pane of glass. One of these boxes is set over a hill of melons, cucumbers or other plants in the field. The box protects the plants against chilling winds and the glass allows the sun to heat the soil. After the plants are well established the box is removed. Most gardeners prefer to start plants in greenhouses and hotbeds and keep them there until the weather is warm enough to set them in the field without danger of frost injury. By the use of paper pots, paper bands, veneer bands, flower pots, etc., practically any kind of crop can be started indoors and transplanted safely to the garden later.

CHAPTER VIII

GROWING PLANTS FOR TRANSPLANTING

Certain crops are practically always started in a seed bed and the plants later transplanted to the field. Among the vegetables started in this way are cabbage, cauliflower, broccoli, Brussels sprouts, celery, eggplant, peppers, tomatoes and sweet potatoes. All of the crops mentioned and many others, such as lettuce, melons, cucumbers, beets, onions, lima beans, and sweet corn are sometimes planted in hotbeds or greenhouses in order to hasten maturity.

Advantages of Starting Plants in Greenhouses, Hotbeds and Cold Frames.—There are many advantages in starting plants in greenhouses or other forcing structures, the most important being: (1) Production of an earlier crop thereby getting advantage of the early market; (2) increasing the length of the growing season by planting seed several weeks before weather would permit of outdoor planting; (3) making it possible to grow long season, tender crops such as tomatoes, peppers, eggplant, melons and lima beans in regions having a relatively short growing season; (4) enabling gardeners to produce more crops on same land; (5) protecting young plants from unfavorable conditions, and disease and insect injury; (6) securing larger yields of many crops, especially the tender, long season plants, such as tomatoes, eggplant, peppers, melons, cucumbers and lima beans, which continue to bear in the North, until killed by frost.

Sowing Seed.—Moisture, oxygen and a congenial temperature are requisites of germination. In greenhouses and hotbeds moisture and a congenial temperature are artificially provided, but to maintain the proper moisture the soil must be of good texture. The soil for the seed bed should be light and friable but not so light that it dries out quickly. A heavy soil, or one containing considerable clay, is not satisfactory because when the surface becomes dry it gets hard and cracks, and if kept wet it puddles and these conditions are not favorable for good germination and growth. A sandy loam soil is most generally used for seed beds, but muck is considered almost ideal for celery, lettuce and some other crops.

The time for sowing seeds in greenhouses, hotbeds or cold frames depends upon the kind of crop and subsequent treatment it is to receive before the plants are to be set in the field. If they are to be set directly from the seed bed less time is given than when they are to be transplanted

once or twice. In general the length of time between seed sowing and setting the plants in the field varies from three to four weeks to three months. There is danger of the plants going to seed prematurely if they are started too early. This often occurs with celery and cabbage. The requirements with reference to the various crops, handled in different ways, are given under the discussion of the individual vegetables.

Small seeds are sometimes sown broadcast and covered very lightly with fine soil or merely covered with a piece of cloth or burlap. The latter method is often used in starting celery plants. Seeds of cabbage, cauliflower, tomato, eggplant, etc., are commonly sown in rows. When flats are used the rows are usually about 2 inches apart, but when sown in the soil of the greenhouses bench, or hotbed more distance is given, from 3 to 6 inches being common. The wider spacing of the rows is given when the plants are not to be "pricked out."

The depth of sowing depends to a considerable extent on the size of the seed and the kind of soil. Very small seeds should be covered very lightly if at all. Cabbage seeds and others of similar size are usually planted about 1/4 inch deep while beet seeds are planted to a depth of 1/2 inch or more. On very light soil seeds may be planted deeper than on heavy soils.

Care of the Seed Bed.—Very close attention must be given the seed bed if good results are to be secured. Only by experience can one learn just how to care for the seed bed under the artificial conditions which prevail in greenhouses, hotbeds and cold frames. The gardener wants good stocky plants ready at the required season and to have them great care must be given to the temperature, moisture, ventilation, transplanting and "hardening off." Things to avoid are: (1) Chilling the plants; (2) overheating and lack of ventilation which make the plants soft; (3) overwatering, which makes the plants soft and very susceptible to "damping off;" and (4) wilting of plants due to too much heat or too little water.

Watering.—Caution should be exercised in watering the seed bed. Before the seedlings come through the surface there is danger of washing out the seed and puddling the soil. At this time the seed bed should be watered with a fine spray from a sprinkling can or with a fine rose on a garden hose. Water dashed on the seed bed through an ordinary hose nozzle or through a rose with large holes is likely to wash out the seed. The seed bed should never be allowed to dry out, nor should it be kept soaked. Until the plants are well established the soil should be kept fairly moist but not wet. After the plants are well established the watering should be done thoroughly but not too often. There is usually more danger of over-watering than under-watering. Keeping the surface wet after the plants are up is favorable to "damping off" hence it is best not to water often but to soak the soil thoroughly and then withhold water

until the plants show the need of it. Of course more water is required on a bright day than on a cloudy or rainy day because of greater evaporation and transpiration under the former. In fact plants should not be watered on cloudy days unless absolutely necessary. Watering should be done early enough in the day to allow the foliage of the plants to dry off before night. It is best to do the watering in the morning, for if done during the middle of the day there is some danger of sunscald and if done late in the afternoon the plants may not dry off before night. Watering reduces the temperature in the hotbed and for this reason it should be done early enough to allow the bed to get warm before the sun goes down. Before the plants are to be taken up to set in the field the plant bed should be thoroughly soaked so as to have as much soil as possible adhere to the roots.

Controlling Temperature.—In greenhouses and in steam or hot-water-heated hotbeds the temperature is controlled by turning on and turning off the heat in some or all of the pipes and by regulating the ventilation. During bright days in spring it is often necessary to turn off all of the heat and ventilate thoroughly to keep the temperature down. The temperature that should be maintained depends upon the kind of crop. Tomatoes, peppers, eggplants, cucumbers and melons thrive best in a relatively high temperature while cabbage, cauliflower, lettuce, celery, onions and beets do best in a relatively low temperature. Slow, steady growth is preferable, therefore the temperature should not be high enough to make rapid, succulent growth nor low enough to check growth until time for hardening the plants.

Ventilation of greenhouses and frames where young plants are growing needs careful attention. Ventilation dries the air and aids in the control of the temperature. In greenhouses ventilation is secured by opening the ventilators, while in frames the sashes are raised at one end or pulled down a short distance. The tendency is to ventilate too little rather than too much. As plants grow, more and more ventilation should be given until finally on bright warm days the sash may be removed. In ventilating during cold weather the wind should not be allowed to strike the plants. In greenhouses this is obviated by opening the ventilators on the side of the house opposite the direction of the wind. In frames the wind is prevented from striking the plants by raising the end of the sash on the side of the frame opposite the direction of the wind.

Transplanting.—Plants started in the greenhouse, or hotbed are usually transplanted once, and sometimes twice or three times prior to setting them in the field or garden. The main advantage of transplanting is economy of space in the greenhouse, or hotbed, although many other advantages are claimed for the practice. Many gardeners and other authorities believe that transplanting develops a more stocky plant, with a better root system and thereby increases the yield and

hastens maturity. The evidence on this point indicates that transplanting, in itself, does not increase the yield nor hasten maturity, but that the increase in space given the transplanted plants does have this effect. In many of the experiments in transplanting the space factor was not eliminated, and other factors also were involved. However, some investigators eliminated all of the factors except the one under investigation. Cranefield (32) in Wisconsin worked with cabbage, cauliflower, lettuce, collards, kale and tomatoes. Lettuce seed of the Grand Rapids variety was planted 6 inches apart in a greenhouse bench with 4 inches of soil on January 15. When the plants attained suitable size one-half of them were taken up and reset in the same places in the usual manner of transplanting. On March 23 the entire crop was harvested and weighed and the weights were as follows:

30 plants not transplanted weighed 1,274.5 grams.
30 plants transplanted weighed 1,093.5 grams.

These figures show an advantage of 16⅔ per cent, in favor of the plants not transplanted.

Cabbage plants not transplanted, once transplanted and twice transplanted gave results similar to the lettuce. The weights of the plants three months after sowing the seed were as follows.

8 plants not transplanted 4,214.0 grams.
8 plants once transplanted 2,993.5 grams.
8 plants twice transplanted 2,241.7 grams.

The following year Cranefield carried on the work in the field, using cauliflower, two varieties of cabbage, kale and collards. The seeds were sown thickly in the row in the open on May 27 and after the plants appeared they were thinned, by cutting off at the surface of the ground, to 3 feet apart in the rows. On June 23 alternate plants were taken up with a pointed stick and reset in the same places. The yields were as follows:

Cauliflower:
18 heads transplanted weighed 58.9 pounds.
18 heads not transplanted weighed 68.0 pounds.
Cabbage, All Seasons:
19 trimmed heads transplanted, 119.3 pounds.
19 trimmed heads not transplanted, 132.6 pounds.

Flat Dutch cabbage, Dwarf Curled Kale and Georgia collards gave similar results, but the number of plants used was too few to give reliable results.

Cranefield grew three crops of tomatoes by sowing seed in 6-inch flower pots. When the plants were about 2 inches high two-thirds of the whole number were dug up and reset in the same pots; later one-

half of these were again transplanted in a similar manner. As soon as the weather permitted 10 plants from each lot were set 4 by 8 feet apart in the open ground. The total yields, from these plants, for the 3 years were as follows:

	Pounds
Not transplanted	1,174.8
Once transplanted	1,131.2
Twice transplanted	1,001.2

In order to judge earliness the picking season was divided into three periods. The yields during the first period (first third of the picking season) were 105.2 pounds on the plants not transplanted, 109.7 pounds on the once transplanted plants and 88.1 on the twice transplanted plants.

More recent results by Boyle (15) in Indiana may be of interest in this connection, although the differences in yield may be due to the space factor rather than to the effects of transplanting. For a discussion of this work see Chapter XXV.

From the results of various experiments it is evident that transplanting checks growth, and that this check is in proportion to the size of the plant at the time it is transplanted. The smaller the plant the less check there is to growth and the more quickly the plant overcomes the check. This probably accounts for the greatly reduced yield on plants twice transplanted. Taking up plants for transplanting results in breaking some of the roots, especially tap-roots and this results in the development of many new roots. Since these new roots do not attain the length of those on similar plants not disturbed a larger proportion of the feeding roots of the plants previously transplanted remain intact when the plants are removed to the field. The feeding area of plants that have been transplanted may be less than that for plants not transplanted, but when the latter are taken up to plant in the field the long roots are broken off, and because of this a much smaller root system may be carried with the plant to the field than is the case with plants that have been transplanted. When plants are grown in pots or plant bands practically all of the roots remain in the ball or block of soil when the plants are set in the field. This probably accounts for the increased yields from plants grown in these receptacles over similar plants grown in flats or in the soil of hotbeds and greenhouses.

When plants are merely shifted from a small receptacle to a larger one there is no breaking of the roots and hence no material check in growth results, even to large plants. This is not at all comparable to taking up the plants from a seed bed, or even taking them from flats in which they have been transplanted.

It is well-known that some plants withstand the shock of transplanting much better than others, but the reasons for the differences are not

known. It may be due to the difference in the character of the root, especially the degree of branching, the proportion of actual root area, the degree and rate of endodermal suberization or cutinization, and the rate of root formation. It may be due to difference in the above-ground portion of the plant, such as size of leaves, changes in the protoplasm which enables some plants more than others to retain water against drying. All of the factors mentioned, and others, may be involved.

Seedlings are planted in flats, or directly to the soil of the greenhouse or frames. Flats are becoming more popular each year because of the

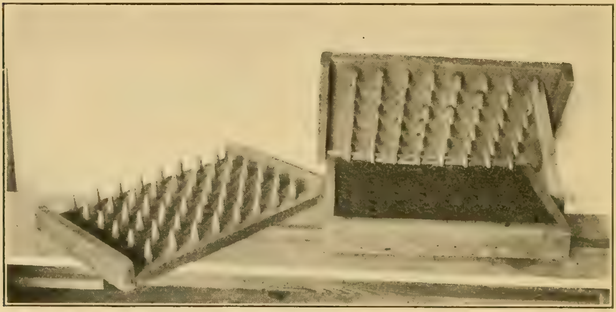

Fig. 2.—Spotting boards used in making holes to receive seedling plants.

following advantages: (1) The work can be done indoors; (2) the transplanting in flats on a table is easier than bending over a hotbed; (3) the plants in each flat are definite in number, which is a great advantage in making sales; (4) the flats can be hauled directly to field and distributed; (5) the plants can be taken up with a large amount of soil adhering to the roots; (6) the plants are less likely to dry out before being set in the field because the roots are not disturbed until the plant is to be set.

Seedling plants are usually transplanted or "pricked out" when the true leaves appear, or when they reach the height of 1½ to 2 inches. The soil for transplanting should be loose and friable and a little richer than that used in the seed bed. When flats are used about ¾ inch of sods or partly rotted manure is usually placed in the bottom to insure drainage. The flat is then filled with soil, which is firmed a little in the corners and along the sides. A leveling strip is used to remove the surplus soil and to leave the surface smooth. Holes for the plants may be made with the finger, with a small dibble, or with a spotting board, Fig. 2. The use of a spotting board is desirable in order to get the plants evenly spaced and to save time.

Seedlings are spaced 1 to 2 inches apart each way depending upon the size of the plants and the length of time they are to remain in the box or bed. Sometimes plants are transplanted twice before being set in the field. As soon as they begin to crowd after the first transplanting they are taken up and transplanted again, spacing them farther apart. If the plants have been planted 2 by 2 inches the first time they may be spaced 3 by 3 or 4 by 4 inches at the second transplanting. Tomatoes and some other plants are often put in paper bands, veneer bands, flower pots, tin cans or other containers at the second transplanting, one plant to each receptacle. The main advantage in using pots, or dirt bands is that the roots are not disturbed when the plant is set in the field as all of the soil around the roots remains intact. In transplanting the soil should be pressed down around the roots, taking care to see that the hole is closed at the bottom. Young, succulent plants are sometimes injured by pressing against the stems with the fingers in transplanting. The pressure should be exerted downward rather than against the plant. After each transplanting the plants should be watered thoroughly to settle the soil round the roots. It is an advantage to shade the plants until they become established. Bright warm sunshine is likely to cause wilting since the roots cannot take up moisture as fast as it is transpired from the leaves.

Seeds of cucumbers, melons, lima beans and sweet corn are sometimes planted in pots, or plant bands a few weeks before time for setting in the open. Several seeds are planted in each receptacle and the young plants thinned to the desired number either before or after planting in the field. In planting in the field all of the soil is kept around the roots so as to check the growth of the plant as little as possible.

Hardening Plants.—The term hardening or "hardening off" is usually thought of in connection with the processes which make plants less susceptible to frost injury, but it also might be used with reference to any firming of the tissues which enables plants better to withstand other unfavorable conditions such as hot sunshine and drying winds. All experienced gardeners know that soft, tender plants are injured by unfavorable soil and weather conditions and effort is made to prevent this by subjecting them gradually to the conditions less favorable to rapid growth.

Among the methods used to "harden off" plants are: (1) Exposing them to relatively low temperatures for a week or more; (2) withholding water; (3) checking growth by allowing the plants to become root-bound; (4) growing plants in poor soil. Rosa (127) has shown that watering plants with M/10 solutions of potassium chloride and sodium chloride also results in hardening. Exposing plants to relatively low temperatures is the most common method employed and this is done by reducing the heat and ventilating the greenhouses and hotbeds or by removing the plants to cold frames. Plants are hardened gradually to prevent a

severe check to growth or possible killing of the tissues. Anything which checks growth increases hardiness to some extent, but subjecting plants to low temperature seems to give the best results in general practice, although this is usually accompanied by withholding water.

How Does Freezing Injure or Kill Plants?—The mechanism of frost injury has been studied by many plant physiologists and many theories as to the cause or causes have been advanced. Frost injury has been ascribed to: (1) Rupture of the cells by growing ice crystals; (2) mechanical effect of ice formation on the plasma membrane; (3) withdrawal of water from the plasma membrane; (4) dessication or direct water loss; (5) the precipitation of proteins through "salting out" and (6) precipitation of proteins by increase in acidity.

Results secured by numerous investigators show quite clearly that cell-rupture cannot be the cause of death of plants by cold. Loss of water from the cells by ice formation in the intercellular spaces invariably accompanies the killing of plants by cold. It has been shown that plant tissues can withstand temperatures several degrees below the freezing point without injury if ice formation does not take place. Thus Wright and Taylor (187) have shown that potatoes can be cooled several degrees below their freezing point and warmed up again without injury provided ice formation does not take place.

Harvey (70) after studying the work of others and conducting elaborate experiments himself, expresses the belief that "all the factors mentioned play an important part, but in addition there appears to be another important factor—the change of the actual acidity or hydrogen-ion concentration of the plant juice on freezing. It seems that this factor supplies the deficiencies of the other factors in explaining frost injury."

Effects of Hardening on Frost Injury.—The hardening process in plants is accompanied by certain easily observed changes such as changes in the color of the leaf and stem and in the texture of leaf; hardening of the stem; slowing of the growth rate and on the leaves of cabbage increase in the amount of bloom. Tomato leaves of hardened plants are paler than leaves of non-hardened plants of the same age. The underside of the leaves often turns slightly purple. Cabbage leaves turn pale green and show pink or purple color on hardening.

There are many theories on the relation of hardening to frost injury. The thickening of the waxy covering or bloom on the surface of the leaves of cabbage and other plants which have been hardened is given as one of the reasons that hardened plants can withstand lower temperatures than non-hardened plants. Harvey (70) states that:

> The undercooling of the cell solution is a factor of great importance in the resistance of cabbage to freezing. Those plants which have the most bloom on the leaf surface are most resistant to the formation of ice within the tissue.

Cabbages which are well covered with wax show no indications of freezing after several hours exposure to a temperature 5 degrees below that at which ordinary plants show ice formation.

In plants which have but little waxy covering greater amounts of moisture stick to the leaves than in those having a heavy covering or bloom. The moisture freezing on the surface inoculates the undercooled solution within the leaf. When once begun, the freezing process is transmitted rapidly through the leaf tissue.

Some investigators claim that the freezing point of the cell sap is lower in hardened than in non-hardened plants and give this as one of the reasons why the former can withstand lower temperatures better than the latter. Others believe that the increase in sugars during the hardening process is one of the causes of reduced injury of hardened plants, ascribing to sugars an important role in the prevention of protein precipitation. Rosa (127) shows that in tomatoes the increase in sugars in hardened plants is relatively slight, while the accumulation of starch is much larger than in cabbage or lettuce.

The lessened injury from freezing after plants have been hardened has been ascribed by several workers to changes in the proteins, a breaking down of the complex forms to simpler forms which are not so easily precipitated. On this point Harvey, in summarizing his investigations, gives the following conclusions or summary:

The principal effect of the hardening process for cabbages is a change in the constituents of the protoplasm which prevent their precipitation as a result of the physical changes incident upon freezing. The proteins are changed to forms which are less easily precipitated. This is indicated by an increase in the amino-acid content of the cabbage plants on hardening.

The factors which produce protein precipitation on the freezing of a plant juice are held to be principally the increase in the hydrogen-ion concentration, and the increase in the concentration of the salts. The latter factor is held to be insufficient to cause precipitation except under the conditions of changed acidity. Cabbage plants were found to become resistant to a half-hours' freezing at -3 degrees C. after exposure to $+3$ degrees for 5 days. During this time the carbohydrate changes were slight. Hence the prevention of protein precipitation by sugar accumulation during hardening is not sufficient to account for the resistance of hardened plants to freezing.

The proteins of the midrib of cabbage leaves are precipitated more readily than those from the rest of the leaf. This is considered to be due to physiological differences between vascular tissues and the other tissues of the leaf.

In juices of non-hardened and hardened cabbages the proteins of the former were found to be precipitated to a greater degree by freezing than those of the latter. The percentage of precipitation for such juices on freezing is closely paralleled by the relative precipitation on the addition of acid.

The greatest changes induced by freezing are supposed to occur in the outer portions of the protoplast since this is most exposed on plasmolysis.

The effects of dessication, freezing and plasmolysis are considered to be similar, in that all these processes cause changes in the hydrogen-ion and salt concentrations.

Rosa (127) presents data which show that the hardening process in plants is accompanied by a marked increase in water-retaining power. He believes that this is due chiefly to the imbibitional forces of the cell. He summarizes the results of his studies as follows:

Any treatment materially checking the growth of plants increases cold-resistance. In cabbage and related plants, hardiness increases in proportion as growth is checked. In tomato and other tender species, the checking treatments resulted in relatively slight increase to cold-resistance. The various means of hardening plants in these experiments have resulted in about the same type of changes within the plant.

Cabbage plants hardened by various treatments contain a larger amount of "unfree," or not easily frozen, water, as measured by the dilatometer. The increment in unfree water corresponds to the extent to which growth is checked, both of these paralleling the degree of cold resistance.

The amount of water frozen at different temperatures in leaves of varying hardiness was measured. The percentage of moisture frozen in hardened cabbage leaves at −3 degrees C. and at −4 degrees C. is about two-thirds of that frozen in tender cabbage leaves at the same temperature. The actual amount of water remaining unfrozen at a given temperature is greater in hardened than in tender leaves, although their total moisture content is less.

The percentage of total moisture frozen in leaves increases for each successive degree of temperature lowering, but the increase becomes rapidly smaller and smaller. The amount of water remaining unfrozen in hardened cabbage leaves is approximately a logarithmic function of the temperature.

Cabbage plants exposed to low temperatures in a coldframe for varying periods have a progressively smaller amount of water freezable at −5 degrees C., the longer they are exposed to hardening. The percentage of freezable water decreased quite rapidly in the first four days after removal from the greenhouse, more slowly from four to fourteen days and very slowly thereafter. The rate of decrease in percentage of freezable water coincides with the observed rate of hardening. In other words, the hardening process in cabbage plants was accompanied by a proportional increase in the amount of water unfrozen at −5 degrees C. The amount of water frozen at −5 degrees C. is somewhat less in plants exposed to slight wilting at midday.

The effects of watering plants with M/10 salt solutions are associated with a condition of mild physiological drought. The degree of such drought is proportional to the concentration of the soil solution, which in turn is influenced by (*a*) the amount of water-soluble material present and (*b*) the power of the soil to hold a large part of the soil moisture unfree in the pure or nearly pure state.

Hardened cabbage plants lose less moisture by transpiration per unit of leaf area than tender plants, under the same conditions. The amount of water lost by transpiration per plant for a given period is much less in hardened cabbage

plants than in non-hardened plants of the same age because of (*a*) the lower rate of transpiration and (*b*) the smaller size of hardened plants. This accounts for the fact that hardened plants can be transplanted to the field with less wilting.

The rate of water loss from hardened cabbage leaves dried in an oven at 60 degrees C. is much less than that from leaves of tender plants. In tomato, the rate of drying is only slightly less in hardened than in non-hardened plants. Comparing the rate of water-loss from tomato and cabbage leaves, it is found that hardened tomatoes lose water somewhat faster than tender cabbage leaves.

The lesser amount of water lost by ice formation, the lower rate of transpiration and the slower rate of water loss upon drying in hardened cabbage plants, may be explained by the hypothesis that hardening develops an increased water-retaining capacity. The water-retaining power of plant cells is due to (*a*) osmotic concentration, (*b*) imbibition and may be increased by means of either or both of these factors.

Osmotic concentration of plant cells may be increased by:

1. Decreasing the total water content.
2. Increasing the amount of osmotically active sap solutes.
3. Decreasing the amount of free water or conversely, by increasing the amount of unfree water held by colloidal adsorption.

Osmotic concentration as measured by the lowering of the freezing point has been found to increase on hardening plants, varying inversely with the water content. Both reducing and non-reducing sugars increase with hardening. Sugars are found to increase more in cabbage and lettuce than in tomatoes. The increased sugar is not sufficient to account for much difference in the freezing point depression or in the amount of water remaining unfrozen several degrees below the freezing point. The chief factor in increasing osmotic concentration in plants is considered to be the decrease in amount of free water, hence the observed increase in osmotic concentration would be a secondary result of the hardening process.

The power of imbibition possessed by plant cells may be increased by:

1. Decreasing the total water content (or increasing the per cent of dry matter).
2. Increasing the amount of hydrophilous colloids in the protoplasm.
3. Increasing the water-retaining power of such colloids by slight increase in acidity, etc.

Decreased water content accompanies a condition of greater cold resistance in plants. During the hardening process, the percentage of dry matter increases rapidly for a few days, and more slowly thereafter. The total pentosan content is greater in hardened than in tender plants, regardless of the kind of hardening treatment. The pentosan content of cabbage plants exposed to low temperatures in an open cold frame during March increases rapidly the first five days and more slowly thereafter. The pentosan content of cabbage, kale and celery plants growing in the open garden increases as the weather becomes colder during the fall. In cabbage, kale and lettuce plants possessing potential hardiness, the fraction of the pentosan content soluble in hot water is larger than in tomato, eggplant and sweet potato, which do not possess potential hardiness. The hot water-soluble pentosan content is thought to represent more nearly the amount of

pentosans in the protoplasm and these might function more specifically as water-retaining material. In the group of plants susceptible of considerable hardening to cold the increase in total pentosan content upon hardening is largely an increase

TABLE XI.—EFFECTS OF VARIOUS METHODS OF HARDENING PLANTS ON THEIR ABILITY TO RESIST LOW TEMPERATURES

(Adapted from Table 2. *Mo. Res. Bull.* 48. 1921)

Plant	Treatment	Relative hardiness to cold
Cabbage	Optimum moisture, greenhouse	Killed at −4 degrees C. in 1 hour.
	Medium moisture, greenhouse	Slightly injured at −4 degrees C. in 2 hours. Uninjured at −3 degrees C. in 2 hours.
	Minimum moisture, greenhouse	Not injured at −4 degrees C. for 2½ hours.
	Greenhouse plants not hardened	Killed at −4 degrees C. in 2 hours.
	Plants hardened in cold frame, 1 week	Slightly injured at −4 degrees C. in 2½ hours. Slightly injured at −6 degrees C. in 2 hours.
	In cold frame, 3 weeks	Slightly injured at −6 degrees C. in 2 hours.
	Compost soils and tap water	Not injured at −3 degrees C. in 30 minutes. Killed at −6 degrees C. in 30 minutes.
	Compost plus $NaNO_3$ M/10	Slightly injured at −6 degrees C. in 30 minutes.
Tomato	Optimum moisture, greenhouse plants (leaves only)	Killed at −2 degrees C. in 1 hour.
	Medium moisture, greenhouse plants (leaves only)	Severely injured at −2 degrees C. in 2 hours.
	Minimum moisture, greenhouse plants (leaves only)	Killed at −2 degrees C. in 2 hours.
	Greenhouse plants not hardened	Killed at −1½ degrees C. in 1 hour.
	Hardened in cold frame for 7 days (leaves only)	Injured at −2 degrees C. in 1 hour.
	Hardened in cold frame 21 days (leaves only)	Uninjured at −2 degrees C. in 1 hour.
Leaf lettuce	Optimum moisture greenhouse plants	Killed at −3 degrees C. in 1½ hours.
	Minimum moisture greenhouse plants	Uninjured at −3 degrees C. in 1½ hours.
	Minimum moisture in warm greenhouse.	Killed at −4 degrees C. in 2 hours.
	Hardened in cold frame for 2 weeks	Uninjured at −3 degrees C. in 3½ hours.
Head lettuce	Head lettuce hardened in cold frame 10 days	Uninjured at −4 degrees C. for 2½ hours.
Cauliflower	Greenhouse plants not hardened	Killed at −4 degrees C. for 2 hours.
	Cold frame hardened	Uninjured at −4 degrees C. for 2 hours.

in the hot water-soluble fraction, while in the tomato the hot water-soluble fraction does not increase upon subjecting the plants to hardening treatments.

It is well known that some plants such as cabbage, lettuce, celery etc. can be made to withstand a lower temperature than tomatoes, egg-

plants and peppers. It is also recognized by gardeners that the extent of the hardening process determines, to a considerable degree, the amount of cold a given plant can stand. Rosa experimented with different methods of hardening including; (1) subjecting plants to a relatively low temperature, (2) watering plants with M/10 salt solutions, (3) growing under different moisture conditions, (4) growing in different kinds of soil and a combination of (3) and (4).

Table XI shows the effects of the different treatments on the relative hardiness of plants to cold.

Harvey (70) secured similar results with reference to temperatures. He found that after 6 days' exposure to 3 degrees C. cabbage plants were not injured by 30 minutes' exposure to −3 degrees C. although frozen stiff. At 18 degrees C. for 5 days two thirds of the plants were killed in 60 minutes exposure to −2.5 degrees C. and when kept in the greenhouse all were killed on exposure to −2.5 degrees C. for 60 minutes. When the plants were hardened for 5 days at 5 degrees C. they were not injured at −2.5 degrees C. in 60 minutes, but when kept at 5 degrees C. for 10 days one-third of the plants were killed at −4.5 degrees C. in 60 minutes.

He found that when plants were taken back into the greenhouse, hardiness was lost in about the same length of time it took to acquire hardiness.

Under natural conditions the hardiness acquired in one night of low temperature may be lost during the succeeding warm day and there is accumulative effect only when the average temperature is low.

Hardening plants by withholding water and by subjecting them to relatively low temperatures are practical methods, but growing them in poor soil is not, because the gardener wants his plants to make good growth. This is impossible in poor soils and for this reason the soil used for growing plants is usually fairly rich, especially when the plants are transplanted before being taken to the field.

The results reported by Rosa (127) give a possible explanation as to why cabbage plants can be hardened so that they will withstand freezing while tomato plants do not possess potential hardiness. He found that acidity was much greater in hardened cabbage and lettuce plants than in unhardened plants, while with the tomato the hardening treatment did not increase acidity. He found also that the increase in water soluble pentosans, due to the hardening treatment, was greater for plants possessing potential hardiness, as the cabbage, than for those which do not possess it, as the tomato.

CHAPTER IX

PLANTING VEGETABLE CROPS IN THE OPEN

The time and method of planting seeds and plants of a particular species in the open determine to a considerable extent the success or failure of the crop. Even with good seeds or good plants satisfactory and profitable crops will not be produced unless the planting is done at the right time and in a proper manner. Attention must be given to the preparation of the soil for the seed bed, to the depth of planting, rate of planting and to various other factors such as thinning and watering to insure a satisfactory stand of plants. Planting both seeds and plants in the open is considered in this chapter.

Time of Planting.—No definite date can be given for planting vegetable seeds and plants, because climatic conditions vary widely within relatively small areas due to differences in elevation, proximity to large bodies of water, etc. The time of planting should be determined with reference to the soil and weather conditions; to the kind of crop and to the time the produce is desired. Earliness is an important factor and most commercial and home gardeners aim to plant their vegetable seeds and plants as soon as it is safe. Vegetable crops may be grouped into three classes with respect to cold resistance: (1) Hardy or those which will withstand hard frosts; (2) half-hardy or those which will withstand light frosts and the seeds of which will germinate at low temperatures; (3) tender or those unable to withstand any frost and the seeds of which will not germinate in cold soil. The hardy group includes kale, spinach, turnip, mustard, onion and smooth peas and seeds of these may be planted as soon as the soil can be prepared in the spring. Cabbage plants, which have been well hardened, may also be transplanted into the open at this time. Seeds and plants of the half-hardy group may be planted two or three weeks before settled weather, or before the danger of killing frost is over. Beets, carrots, parsnips, celery, (seed and hardened plants) lettuce, wrinkled peas and chard belong to this group. The third group includes beans, sweet corn, lima beans, squash, pumpkin, melons, cucumbers, okra, tomato plants, eggplant and pepper plants. Sweet corn and beans will withstand more cold than the others in this group and are often planted before danger of frost is over. It pays to take some chances on most crops which are grown from seed planted directly in the field, since the cost of seed and labor of planting are usually not large items and earliness means much in marketing the crop.

When more than one planting is made of any crop the second and later plantings should be timed so as to have a continuous harvest. This is especially important with beans, sweet corn, spinach, lettuce and many other crops, which deteriorate rapidly in quality as they become old.

Depth of Planting Seeds.—No definite rules can be given regarding the depth to plant seeds of various kinds. The size of the seed, the kind of soil and the amount of moisture in the soil should be considered. Large seeds are planted deeper than small seeds, although it does not follow that the largest seeds should be planted the deepest. Kidney beans and lima beans are not usually planted as deep as peas, because unlike the pea the young bean plant pushes the cotyledons up through the soil and if the covering is too deep they may be broken off and the plant thereby injured. Small seeds, as celery, are often merely pressed into the soil or covered with burlap or other similar material. On light soils such as fine sand or sandy loams, seeds are planted to a greater depth than on heavy soils. The more moisture there is present in the soil the less the need there is for deep planting and for this reason seeds are usually given a relatively light covering in the spring. The same kind of seeds planted in late summer require greater covering because the surface layer of soil is usually drier and it is necessary to place the seed at a greater depth to secure sufficient moisture to insure germination and to bring the plant to the surface.

Marking Rows.—Straight rows and even spacing are important in growing vegetables on a commercial scale. Straight rows add to the appearance and also make cultivation easier and more rapid. In spraying celery and other crops with a power sprayer straight rows and uniform spacing are essential to good work. The spray nozzles are usually set certain distances apart, and, while they can be changed, it requires much time to adjust them for each set of rows to be sprayed.

Straight rows can be secured by using either a line, or markers of various kinds. When drills are used for planting seeds a line should be used for the first row and the marker attachment used for the remainder. The operator needs to take considerable pains to keep the rows straight when using the marker on the seed drill, or when marking the rows with a hand marker. The most careful and painstaking men should be used for marking out the land and sowing seeds with a drill.

Methods of Planting.—Most commercial gardeners plant seeds with machine planters of some kind. Machines do the work much better and more rapidly than is possible by hand sowing. The common seed drills open the furrow, drop the seeds, cover them and pack the soil at one operation. These drills can be regulated to sow at various rates and at the depth desired. By regulating the rate of seed-sowing, thinning can be reduced to the minimum. There are several makes of seed drills on the market and all of them are satisfactory when properly used.

Sowing seed by hand is commonly practiced in home gardens, as too small quantity of any one kind of seed is used to justify the expense of a seed drill. It would be necessary to adjust the drill to the different kinds of seeds and the time required to do this would often be enough to do the planting by hand. A garden line or marker should be used when planting is to be done by hand in order to secure straight rows. The furrow for small seeds may be made with the rake or hoe handle, using the same kind of a motion one uses in sweeping. For large seeds the furrow may be made with the corner of an ordinary hoe; with a heart-shaped hoe; with the plow attachment; or with one of the cultivator teeth of a wheel hoe. The seeds should be distributed uniformly in the furrow. Small seeds such as radish, turnip, lettuce, etc. may be sown direct from the seed packet or from an envelope with the end cut open, by moving it slowly over the row and tapping it lightly with the finger. The seeds should be covered immediately to prevent loss of moisture from the soil. After covering the seeds the soil, if dry, should be firmed by trampling or by tamping with the back of the hoe. This is especially important when the soil is quite dry as it brings the seed into close contact with the soil particles and makes capillary action stronger. The seed drill has a broad wheel which packs the soil over the seeds.

Rate of Planting.—Among the points to be taken into consideration in regard to the amount of seed to plant are: (1) The viability of the seed, (2) the time of planting, (3) the condition of the soil, (4) the size and vigor of the young plants and (5) the possible ravages of insects.

Seeds of low viability should be planted more thickly than those having a high percentage of germination. In order to determine the rate of seeding a germination test should be made in advance. If the percentage of germination is low, or if the sprout is weak the seed should not be planted, for a poor stand of weak plants would result.

Seeds planted when the soil and weather conditions are unfavorable to quick germination should be planted at a heavier rate than when the conditions are favorable. In early spring when the soil is cold, and in late summer when the soil is very dry and the weather hot the rate of seeding should be heavier than when the temperature and moisture are favorable. The longer the time required for germination of any given kind of seed the heavier should be the rate of planting.

Seeds which produce delicate weak plants, such as carrots and parsnips, should be planted quite thickly to insure a good stand. Any excess of plants may be removed to prevent crowding.

In planting seeds of melons and cucumbers it is a common practice to plant freely in order to have several times as many plants as are needed. In most regions it is expected that the cucumber beetle will seriously injure, or even kill many of the plants. Unless large numbers are started the chances are against saving enough for a good stand of strong plants.

After the beetles have disappeared the plants may be thinned to the desired distance apart.

Thinning.—This is an important operation when seeds are planted where the crop is to mature for more plants usually come up than are needed, and, unless some are removed, injury by crowding will result. Thinning may be made a process of selection. The weakest plants should be discarded and the strongest left to grow. By thinning a uniform stand is secured, but as this is a tedious and expensive operation gardeners try to avoid it as much as possible by planting the proper amount of seed and distributing it evenly. There is a tendency among gardeners to delay thinning too long and this results in the plants that are to be left being relatively weak. Thinning should be done as soon as there is reasonable assurance that the plants left will not be killed by unfavorable weather conditions, or destroyed by insects which are injurious during the early stages of the plants' growth.

Transplanting.—Success in transplanting plants to the field or garden is dependent upon good plants, good condition of the soil and doing the work in the proper manner. The plants should be well-grown, stocky and well-hardened to withstand the changed conditions. Slender, unusually soft or succulent plants do not withstand unfavorable soil and weather conditions as well as hardened plants. It is well known that hardened plants will withstand a lower temperature than plants not hardened, but it is not so well known that hardened plants also suffer less from dry or hot weather.

The soil should be thoroughly prepared prior to transplanting. It is very difficult to set plants properly in hard, lumpy soil and plants set under these conditions are likely to be seriously checked in growth, or to become weak and die.

The best time to set plants is just before, or just after, a rain, especially if the weather is cloudy. Cool, cloudy weather is desirable because evaporation and transpiration are less under these conditions than in hot, dry weather. When it is necessary to transplant in hot, dry weather it is desirable to do the work in the late afternoon if possible in order that the plants may have time during the night to recuperate from the shock of transplanting. However, with soil in good condition, plants that have been previously transplanted and well hardened can be set even during hot, dry weather without much wilting if they are taken up with a block of earth around the roots. Plants that have not been transplanted previously and are pulled from the seed bed without any soil adhering to the roots should be watered when the soil is very dry.

Plants are set by hand or by machines of various kinds. When setting by hand, various methods are used. For plants that have been transplanted prior to field planting, it is usually the custom to take them

up with considerable soil around the roots, and in setting them a furrow is made with a small plow, or a hole large enough to take in the block or ball of soil is dug with a trowel, shovel or spade. For large plants like tomatoes a one-horse turn plow may be used to good advantage for opening the furrow. The plants are set in the furrow and earth is packed around each with the hand and the remainder of the furrow is filled with a cultivator. The plow attachment of a hand cultivator, such as the Planet Junior, is valuable for opening furrows for cabbage, lettuce, celery and similar plants which have been transplanted previously. The depth of the furrow can be regulated to suit the size of the plants. The best tool for making a hole for transplanting plants which are taken direct from the seed bed is the dibble. This tool makes a hole without removing the soil. The dibble is held in one hand and the plant in the other and after the hole is made a plant is inserted and then both hands are used to firm the soil around the roots, or the dibble may be used to press the soil against the plant. Care should be taken to see that the soil is firmed around the roots and that no space is left unfilled at the bottom of the hole. The trowel and spade are also used in setting plants either in the same manner as the dibble, or in digging holes for receiving the plants. There are small hand planters on the market similar to the one shown in Fig. 3, which work very satisfactorily in good soil. A small tank on the side for water may be used if desired. By tripping the lever at the top a small amount of water is applied around the roots of the plant, but this method of watering is practicable only on a small scale.

Fig. 3.—A small hand planter used for setting plants in the garden or field. (*Courtesy of Master's Planter Co.*)

Large scale planting of cabbage, sweet potato, tomato and similar plants is often done by means of a transplanting machine. These machines do the work better and more rapidly than is commonly done by hand. These machines open the furrow, apply water and firm the soil around the roots at one operation. Three persons and two horses are necessary to operate this type of transplanter. One man drives and two men, or two careful boys, alternate in placing the plants in the furrow at the proper distances. Shoes close the furrow and press the soil against the roots and stem. For close planting (15 inches) the team must walk slowly and the men or boys work rapidly to get the plants properly set. The water is applied from the barrel through a hose which ends just in front of the shoes of the transplanter. Transplanting machines are not used to very good advantage in setting large plants which have soil

around the roots as is usually the case with transplanted ones; therefore such plants are generally set by hand.

Plants should be set slightly deeper than they were in the seed bed. It is an advantage to set long slender plants quite deep as this will keep them from being whipped by the wind, and, with some plants as the tomato, roots will grow from all of the joints below the surface of the soil. Care must be taken not to set celery and lettuce plants so deep that the crown will be buried.

Watering.—A plant set in very dry soil should be watered unless there is a block or ball of moist soil around the roots. The water should be applied around the roots and the wet soil covered with dry earth to prevent baking. In hand planting a little soil is usually packed around the roots and then the water is poured into the depression. After the water disappears the hole is filled with dry soil. The transplanting machine applies the water about the roots and in such small amounts that the surface of the soil is not puddled.

When watering is not practicable the roots of the plant are often puddled prior to setting. This is done by dipping the roots into a thin paste made with clay in water. Puddling prevents drying of the roots and also causes the soil particles to adhere to them when planted. The mud paste should not be allowed to dry on the roots as this would cause injury by preventing the moist soil from coming into contact with them. The puddling should be done just before planting or else the puddled plants covered with moist burlap, moist moss, straw or other material to prevent evaporation of moisture in the paste. Puddling requires much less labor than watering the plants and gives quite satisfactory results when properly done. When plants are watered after being planted it is desirable to cover the moist soil with a little loose, dry earth to prevent rapid drying and consequent baking and cracking.

CHAPTER X

CULTIVATION

The term cultivation may be applied to any operation which has for its object the stirring of the soil after a crop is planted. It is the intertillage of crops and may be accomplished by means of hand tools, such as hoes, rakes, hand cultivators, etc. or by larger implements drawn by horses or tractors. The main objects of cultivation are to control weed growth and to keep the surface of the soil loose.

Benefits Derived from Cultivation.—Many theories have been advanced to explain the benefits of cultivation and many experiments have been conducted to determine the factors responsible for its beneficial effects on crop plants, especially corn. Among the factors thought to be responsible for the beneficial effects of cultivation are:

1. Conservation of moisture due to the breaking of the capillary film in the formation of a soil mulch, and thereby checking evaporation from the surface.
2. The destruction of weeds. This is a conservation measure as weeds rob crop plants of both moisture and mineral nutrients, and in addition crowd or shade them, causing weak growth.
3. Increase the rate of nitrate formation and the release of mineral elements in the soil due to moisture conservation, increased aeration and increase in growth of soil organisms.
4. Increased aeration. Breaking up of the surface crust is thought to increase aeration, but it has not been definitely proved. Aeration is supposed to be beneficial because of the effects of the air on nitrification, and on the chemical changes in the mineral elements in the soil. It is also claimed that aeration hastens the oxidation of injurious substances in the soil.
5. Increased growth of soil organisms, especially those that are beneficial, such as nitrifying bacteria.
6. Increased absorption and retention of heat.

While all of the factors mentioned may be affected by cultivation the conservation of moisture, due to the destruction of weeds is probably the most important benefit derived from stirring the soil. Moisture conservation probably influences all of the other factors. That the destruction of weeds is the most important benefit derived from cultivation of corn has been proven by many investigators. In fact, it has been shown that keeping down weeds, without stirring the soil, has given practically as good results as cultivation as far as corn is concerned. Experiments have shown no appreciable conservation of moisture due

to the maintenance of a soil mulch, in corn fields, provided weeds were kept down by scraping or cutting off at the surface of the ground.

Cates and Cox (22) express the opinion that the very extensive root system of the corn plant acts as an absorbing mulch and that practically none of the capillary moisture reaches the surface to be lost by evaporation. This, they believe, accounts for the fact that cultivation of corn has not been found beneficial from the standpoint of moisture conservation. Other investigators have expressed similar opinions.

Sewel (132) after a thorough review of the literature on tillage states:

> In general we may conclude that the prevailing theories advocating deep plowing and frequent cultivation are not founded upon experimental results. . . Cultivation may be necessary only to kill weeds and to keep the soil in a receptive condition to absorb rainfall. Thus it is practicable, except on very heavy soils, to reduce the amount of cultivation where the guiding policy is that of thorough cultivation in order to maintain a soil mulch.

In vegetable growing it has been thought that maintaining a soil mulch is the most important object of cultivation. This idea is based very largely on theory, since very little experimental work has been done on this problem.

Experimental Work on Vegetable Cultivation.—In 1919 G. K. Middleton, a graduate student at Cornell University, began a study of the effects of cultivation of various vegetables on yields, soil moisture and other factors. The work was continued by the author in 1920 and results summarized in a paper read before the American Society for Horticultural Science (158). While these experiments are not at all conclusive as regards benefits derived from cultivation they show that crops differ in their responses to it. In both 1919 and 1920 the yields of onions on plots cultivated once a week was heavier than on plots that were scraped to keep down weeds. Carrots, on the other hand, were not benefitted by cultivation as compared to scraping to keep down weeds. Celery and cabbage differed materially in their response to cultivation. Cultivated plats of celery produced a much larger yield than the scraped plats while with cabbage the reverse was true. Lettuce was benefitted by cultivation, even when weed growth was not a factor. Yields of tomatoes were nearly the same on scraped and cultivated plats, but slightly in favor of the latter.

Soil moisture determinations made in 1919 show that maintaining a soil mulch by cultivation conserved some moisture in the soil where onions were grown. With carrots cultivation did not conserve moisture. The average moisture content of the soil to the depth of 30 inches in the scraped plats of onions was 12.65 per cent while in the plats cultivated once a week it was 13.66 per cent on the dry soil basis. This shows a difference of practically 1 per cent in favor of cultivation. The average

moisture in the soil of the scraped plats of carrots was 14.52 per cent and in the plats cultivated once a week it was 13.84 per cent or a difference of 0.68 per cent in favor of scraping to keep down weeds. The difference in the character of top growth and in the amount and distribution of the root system may account for difference between carrots and onions in their response to cultivation for purposes other than the control of weeds. The top growth of carrot is much heavier and shades the ground more than the top growth of onions. This would undoubtedly make some difference in the loss of moisture by evaporation from the surface.

A study of the root systems of onions, carrots, cabbage and celery made in 1919 and 1920 gives a possible explanation of the differences in the response of these to cultivation as compared to scraping to keep down weeds. Very few roots of the full-grown onion plants, grown on Dunkirk gravelly, sandy loam soil, were found at a depth of 10 inches, though one or two reached the depth of 20 inches. The greatest lateral extent was 12 inches, but very few reached out more than 6 inches and the main root zone was found within a radius of 6 inches. A space of 6 to 12 inches wide in the center between the rows, 18 inches apart, contained very few roots. This means that the moisture rising in the soil by capillarity would not be intercepted by roots in the 6 to 12-inch space between the rows. Nor would the roots be broken to any great extent by cultivation late in the season when the cultivator is not run close to the plants.

Carrot roots were found to fill the soil much more extensively than the roots of onions. The tap root and several large roots arising from the side of the carrot were found to have reached a depth of 30 inches. These roots produced numerous branches which were divided and sub-divided. Directly beneath the plant the soil was well-filled with roots to the depth of 25 to 30 inches. A space 4 to 6 inches between the rows, 18 inches apart, was not so well filled although at a depth of 4 to 8 inches many roots met and crossed in the centers. The root system of the carrot is much larger than that of the onion and reaches to a greater depth.

Celery roots were found largely in the surface 6 inches of soil and within a radius of 6 inches of the plant. There was a distinct line between the surface soil and the subsoil, most of the roots stopping at the subsoil although a few reached the depth of 24 to 27 inches. The soil to a depth of 6 inches and within a radius of 6 inches of the plant was well-filled with fine roots, but a space 12 to 18 inches wide between the rows (3 feet apart) contained practically no roots. There was no tap root, but from 30 to 50 large lateral roots grew out from the base of the plant in all directions and these were covered with fine branches throughout their length. These fine roots were not sub-divided. In addition to the larger roots hundreds of small, fibrous roots, 6 to 12 inches long grew out from the base of the plant and these were not branched.

Cabbage roots were found to the depth of 30 inches, even the finer roots being found in considerable numbers as deep as 24 inches. However, a large part of the root system was found in the surface 12 inches of soil. The roots extended laterally as far as three feet and were about as plentiful midway between the rows as within a few inches of the plant. The soil between the rows was well-filled with long slender roots to the depth of 6 inches, although the greatest mass was found within 3 inches of the surface. Since the roots of cabbage so thoroughly filled the soil, most of the capillary moisture was probably intercepted before it reached the surface. Many of the roots near the surface were broken by cultivation even though the work was done with hand cultivators.

When to Cultivate.—In all tillage operations timeliness and thoroughness are of great importance. Where the maintenance of a soil mulch is important cultivation should be done whenever the soil becomes packed or a crust is formed, regardless of the number of times. Many of the best gardeners cultivate as soon as possible after every rain in order to break up the surface crust and to destroy weeds. For destroying weeds the best time to cultivate is just as they are breaking through the surface because at this time the roots are small and do not have much of a hold on the soil. When weeds are destroyed while very small moisture and mineral nutrients are saved for the crop plants. Large weeds are difficult to eradicate with the ordinary cultivators and for this reason it is best to cultivate before the weeds have become firmly rooted in the soil.

No definite rule can be given as to the best time to cultivate each kind of crop under different conditions. The best practice for one crop may not be the best for another and what is good on one type of soil may not be satisfactory on another. Until more experimental data are available the practice of cultivating whenever weeds start or a crust forms on the soil will probably be recommended. The practice followed by some gardeners of cultivating once a week or oftener, regardless of weeds and regardless of the condition of the soil, seems to involve an unnecessary expense. When there is no weed growth and when there is a good mulch on the surface nothing is accomplished by stirring the soil, unless the moist soil below the mulch is reached and in this case moisture is likely to be lost. Bringing moist soil to the surface hastens the drying process and, during a period of drouth, injury to the crop plants is the result.

Shallow vs. Deep Cultivation.—Shallow cultivation is generally recommended because plants are less likely to be injured by having their roots broken than where deep cultivation is practiced. In addition to this, when it is desirable to conserve moisture, deep cultivation is objectionable on account of bringing the moist soil to the surface to be dried out by evaporation. In the spring, when it is desirable to have the surface soil dry out, and to prevent packing, deep cultivation may be justified, but

under other conditions it is not advisable. Practically all of the benefits derived from cultivation are secured through shallow cultivation. The depth that it is safe to cultivate depends upon the stage of growth and upon the character and distribution of the root system. When the plants are small and the roots have not spread very much deep cultivation is not likely to be injurious unless the cultivator is run too near the row. Where deep cultivation is practiced during the early stages of growth the depth should be lessened as the plants grow larger and root development increases. As has been indicated, some crops, and possibly all of them, are injured by deep cultivation, but some are more injured than others. Plants which have a considerable portion of their feeding roots near the surface (3 or 4 inches) are more injured by deep cultivation than those whose roots are largely below the surface 4 inches of soil. Cabbage plants are undoubtedly injured by any kind of cultivation late in the stage of their development because of injury to the roots. Unless cultivation is necessary to keep down weeds it may do more harm than good when the cabbage crop is more than half grown.

Cultivating Implements and Tools.—There are at present three general types of cultivators on the market, *viz.*, horse, tractor and hand cultivators. All of these types may be provided with various attachments such as shovels, scrapers, teeth, disks or rakes. The shovel and teeth attachments are the ones most commonly used in ordinary cultivation, but where the weed growth is very troublesome the scraper attachments are often employed. In the South the "sweep" is very often used in cultivating vegetables as well as corn and cotton, but it is best not to let weeds get such a start that this is necessary. The sweep cuts off the weeds, but leaves bare, scraped soil behind the sweep stock.

Two-horse cultivators are sometimes used for cultivating sweet corn, tomatoes, cabbage and other crops grown on a large scale, but in most gardening operations the one-horse cultivator, with shovel or teeth attachments, is more common. For large scale production of crops the two-row or at least the two-horse, one-row cultivator will be found more economical than the one-horse cultivator. For careful work on crops planted in rows 3 feet or less in width, the one-horse cultivator with five shovels or the harrow cultivator with 11 to 15 teeth is more satisfactory than the larger type. Small teeth are preferable to shovels for most cultivation as the former leave the surface smoother, bring less moist soil to the surface and usually do not run as deep.

Large tractors are not used to any great extent for pulling cultivators in the growing of vegetables, although they are used by many growers for soil preparation. Within the past few years several types of garden tractors have been put on the market. These range all the way from tractors large enough to pull a fair-sized plow down to those that pull only light cultivators. Some of these are recommended for all garden

operations from soil preparation to planting and cultivating while others are made especially to pull cultivators. Garden tractors have not been in use long enough to justify definite statements as to their value. Some gardeners have used them with entire satisfaction while others using the same makes of tractors condemn them as impracticable. They undoubtedly have their place and will be used more and more, but their limitations must be recognized by both the manufacturers and users. Very few garden tractors will do satisfactorily all of the work the sales agents claim for them. It seems safe to say that a tractor large enough to do good plowing is too large for light cultivation and need not be differentiated from ordinary farm tractors by calling them "garden tractors." With improvements that will undoubtedly be made, as experience indicates the need of them, garden tractors may be expected to become of greater value and be used to a much greater extent than they are now.

Hand cultivators or wheel hoes are used to a very large extent by market gardeners and truck growers who cultivate the smaller, more intensive crops. Practically all of the onions and lettuce grown on muck soils, and even on other types of soil, are cultivated with hand cultivators. This type of cultivator saves a large amount of hand hoeing and weeding, and enables the grower to have rows much closer than would be practicable were horse cultivation to be given. Hand cultivators can be used when the crop plants are very small and this enables the gardener to keep ahead of the weeds. The attachments most commonly used are the teeth, usually three in number; and the knives, two in number, which run horizontally beneath the surface of the soil, cutting off the weeds and leaving a mulch. The disks are used to a considerable extent for throwing the soil away from the plants prior to weeding, especially for celery and onions, when the plants are quite small. A great variety of hand cultivators is available to meet the needs of all classes of gardeners and all kinds of gardening.

Hoeing and Weeding.—Intensive gardening requires considerable hand-hoeing and weeding, and even in less intensive types of gardening this work must be done to some extent. The hoe and similar tools are used to keep down weeds and to form a mulch between the plants in the row just as cultivators do this work between the rows. No matter how carefully the cultivating is done some hoeing and weeding is desirable if not absolutely essential. With good cultivation and hoeing very little weeding needs to be done by hand on most crops, but with onions, lettuce, celery and root crops, especially on muck lands, hand weeding is one of the most expensive and most laborious operations. In hoeing the aim should be to destroy the weeds and leave the surface smooth with a light mulch of fine soil. The tendency among gardeners is to reduce hoeing and weeding to the minimum and to do most of the work with cultivators and weeders.

CHAPTER XI

IRRIGATION

In arid regions vegetables are grown commercially under irrigation and in semi-arid regions irrigation is essential to success in commercial gardening. Even in humid regions of the East and South irrigation is used to a considerable extent in market gardening on high-priced lands. With the development of the overhead system there has been a great increase in the acreage of vegetables grown under irrigation in the humid sections of the United States, especially in the Atlantic Coast States. Market gardeners in all regions are becoming more and more interested in irrigation each year as they learn the value of water at critical times in the growth of vegetables.

Benefits of Irrigation.—In arid regions irrigation is absolutely essential to the production of vegetables, while in humid climates it is an insurance. Gardeners never know when a drouth may occur which will practically wipe out the crop, or materially reduce the yield.

Ross Brothers of Pennsylvania report (*Market Growers Journal*, May 1, 1921) a return of $2,776 worth of vegetables from one acre of land under irrigation in 1920, besides a considerable quantity of vegetables for home use. Many other growers have produced enormous yields of crops under irrigation.

Control of moisture conditions makes it possible to produce larger yields and better quality. Continuous growth is essential to high quality and it cannot be assured without artificial watering during most growing seasons.

Irrigation is often of special value just after the seeds are planted as moisture is essential to germination. At transplanting time irrigation is very important if the soil is at all dry.

Methods of Irrigation.—There are three general methods of irrigation in use, spray, surface and sub-irrigation. Surface irrigation may be by means of furrows or by flooding. Both of these types are used extensively in the arid sections of the United States, but have not become popular in the East.

Furrow irrigation is merely running the water through furrows between the rows of plants, while irrigation by flooding is the spreading the water over the fields or parts of fields. The latter method is not applicable to most vegetable crops. Any surface method of irrigation calls for nearly level land and for this reason has not been used to a great

extent in the East where the soils will not permit of much grading. It is claimed that with nearly level land, very little expense is involved in the making of furrows and the outlay for equipment is not as great as with spray irrigation. The main disadvantages of this system are; (1) It requires considerable attention to operate it; (2) it is not practicable on open porous soils because of the loss of water; (3) it does not evenly distribute the water; (4) it causes serious puddling and subsequent baking of the soil in the furrows on heavy clay. However, where the land is nearly level and a supply of water is near at hand this method can be used to advantage. Where a stream can be diverted and water run in the furrows by gravity or where flowing wells are available furrow irrigation is the cheapest form.

Irrigation by flooding is used in growing Bermuda onions in Texas and other varieties of onions in other sections of the West and Southwest. This method is applicable only on level or nearly level land.

Sub-irrigation.—This is a good system of supplying moisture to plants, but is not practicable except in regions where flowing wells are found, because too much water is required. The advantages claimed for sub-irrigation are: (1) A constant water supply; (2) the surface is kept dry thereby maintaining a mulch, which prevents rapid evaporation; (3) the soil is not puddled, and therefore, the surface does not bake afterwards. The main disadvantage is the large amount of water required. Sub-irrigation is not satisfactory where the subsoil is porous nor where a hardpan or impervious subsoil is near the surface.

In Florida sub-irrigation is used to excellent advantage at Sanford and elsewhere in the production of celery, lettuce and other crops. Spencer (140) gives the following as essentials for successful operation of sub-irrigation systems:

1. An abundance of water is necessary. This is usually supplied by artesian wells, obtained by driving iron pipes down into the artesian stratum, and allowing the water to rise in the pipe to a height somewhat above the surface of the ground. The water can also be brought to the surface with force pumps where it rises to within easy reach from the surface.

2. A subsoil or floor, composed of clay, marl or hardpan, located at a depth of 3 to 5 feet below the surface to hold the water and prevent its escape downward.

3. A foot or more of coarse sand on top of the sub-soil or bottom of the irrigated depth that will readily absorb and distribute evenly the water to be used in grading the artificial water table.

4. A top soil of sandy loam that is neither too porous nor too compact, and which will convey the water freely by capillary attraction.

5. Land that admits perfect drainage. It should have a fall of about 1 inch to 100 feet.

6. Land that is level without depression or raised places.

In Florida the laterals are made of 3-inch drainage tile with the lines 24 feet apart. They are placed about 18 inches deep and have a fall of at least 1 inch to every 100 feet.

Spray Irrigation.—Overhead spray irrigation is the method most commonly used in humid regions. By this method water is applied to the surface of soils in the form of spray or mist. This method is an outgrowth of city lawn sprinkling. The advantages of this method are: (1) As the water is applied in a mist it causes no washing of the soil; (2) it distributes the water with more uniformity than in the other systems; (3) it can be used on uneven land and on any kind of soil; (4) it is more economical of water than any other method; (5) it requires less labor to operate than the surface method; (6) it may be used to apply liquid fertilizers through the water pipes; (7) it is sometimes used to prevent blowing of muck soils and to prevent frost injury under certain conditions.

The cost of installing an overhead irrigation system is high, and therefore is justified in humid regions only where the crops to be grown are high priced. Williams (183) makes the following statement regarding cost:

> The cost of spray-irrigation systems depends upon the type installed as well as upon conditions peculiar to each farm. A portable outfit may cost as little as $50 per acre for the field equipment, while a stationary distribution system may cost as much as $150 per acre. To these figures must be added the cost of the main pipe line leading from the water supply and of installing a pumping system. These additional items may bring the total outlay per acre up to two or three times the cost of the distribution system, especially on small acreage. Assuming a cost of $250 per acre on a stationary plant for a small acreage, the farmer should be able to increase his annual returns to cover the following charges:

6 per cent interest on $250	$15.00
5 per cent depreciation on equipment	12.50
2 per cent maintenance and repairs	5.00
Cost of fuel oil at 4 cents per 1,000 gallons of water pumped for 6 acre-inches	6.50
Labor in irrigating, 1 man 6 days at $2	12.00
Total overhead and operating expenses	$51.00

> To realize a fair profit from the irrigation plant, the crops must increase the value something more than $51 per acre.

Of course, the costs of the materials and labor vary from time to time. The amount of water to be applied also influences the cost of operation and the figures given refer to 6 acre-inches per year, the amount normally needed in the Atlantic Coast states. In arid regions much more water is required.

Amount of Water Required.—The amount of water required depends upon the use to which the irrigation is put; the amount and distribution of rainfall; the character of the soil; and the crops grown. For seed

beds in humid regions $\frac{1}{4}$ inch is often sufficient at each application and in maturing garden crops $\frac{1}{2}$ to 1 inch may be applied. Gardeners in humid regions do not average over 6 irrigations per year, therefore, a 6-inch supply of water for the growing season would be sufficient. A sandy soil requires more water than heavier soils and long-season crops need more irrigation than short-season crops.

According to Williams sufficient water to cover the land to the depth of 1 inch per week in humid climates and $1\frac{1}{2}$ inches per week in arid regions is believed to be safe for designing purposes. One acre-inch equals 27,152 U. S. Gallons.

Installing an Overhead System.—Williams (183) gives the following directions regarding the installation of a permanent overhead spray system:

Each overhead spray plant should be modeled to fit the field and conditions under which it is to operate. Assuming that water supply has been developed, there are three major parts to any system which should be considered in the order given. First, type and location of nozzle lines; second, type and location of main feed pipe: third, type and location of pumping plant. The nozzle lines should take the direction most desirable to cultivate the field, so that the crop rows will be parallel to the rows of supports. In general, nozzle lines should run perpendicular to the main feed pipe. The entire field system should be designed to use the minimum amount of large pipe, which generally means to run the main as straight as possible, keeping the nozzle lines in sizes not to exceed $1\frac{1}{2}$-inch pipe.

The size of pipe to use in a nozzle line depends upon the length. The end connecting with the feed pipe must be sufficiently large to carry the full head of water. As the water is diminished by each nozzle the pipe can be reduced in size, finishing with a $\frac{3}{4}$-inch pipe at the extreme end.

Nozzle lines are spaced such distances apart as will best fit the field within a range of 50 to 56 feet. The type of nozzle line depends principally upon the method used for supporting the pipe. The three popular methods are: On tall posts, on short posts, or on cables suspended from high posts.

When tall posts are used they are set in the ground $2\frac{1}{2}$ to 3 feet and cut off about $6\frac{1}{2}$ feet above the ground. These posts are spaced 15 to 20 feet apart and the nozzle line placed on the tops in roller bearings in the case of long lines and between nails in short lines. If the post is of wood it should be not lighter than 4 by 5 inches, but a round post 5 to 6 inches in diameter will serve as well. A more durable but expensive post can be made from a 1- or $1\frac{1}{4}$-inch steel pipe set in a base of concrete 6 inches in diameter and 2 feet deep. Special concrete posts also make excellent supports.

Where wooden posts are used it is advisable to treat the part going into the ground with a good grade of paint, tar, or creosote, to help preserve the wood. The treatment should extend 6 inches above the ground surface.

The tall posts permit the passing of horses or men under the pipe and obviate obstruction to cultivation. This is the most popular method and makes a good appearance when the posts are carefully lined and cut off at the tops so that the pipe will lie straight, or uniformly curved with the surface of the ground.

If short posts are used they are set in the ground 2 to 2½ feet and cut off 1 to 3 feet above the surface. They are spaced 18 to 20 feet apart and the nozzle line placed on top between nails or in roller bearings. A 4 by 4-inch post serves well for this type, but should be treated as are tall posts. This construction is the least expensive but may cause a somewhat closer spacing of nozzle lines if a low hydraulic pressure is to be used. This type also is somewhat in the way of cultivation and is not efficient for tall-growing crops When nozzle lines are made portable on short posts, posts may be made of ¾-inch pipe sharpened and fastened to the nozzle line so that supports are moved with the pipe.

Where high posts and cable suspension is used the posts are spaced from 100 to 200 feet apart and the nozzle line suspended from a tight cable or wire strand which takes the form of a catenary curve between posts. Telephone poles 8 to 10 inches at the base and 6 to 8 inches at the top can be used. A length of 2½-inch steel pipe which may be filled with concrete makes a more substantial post. Wooden posts or black-steel posts should be painted with tar or treated with creosote. The posts should be considerably higher than the nozzle line depending upon the distance between posts and the weight to be supported. It is well to set the bases of the posts in beds of concrete about 18 inches in diameter and 3 feet deep. The end posts and cables must be well anchored with guys fastened to wooden or concrete "deadmen." A 5-foot anchor rod should be attached to the deadman and extended above the surface with an eye where a turnbuckle and a guy wire can be attached. Single guys are used where the tops of the end posts of several lines can be connected with a guy wire perpendicular to the nozzle lines, otherwise double guys should be used. The deadman should be at least a distance equal to one-third the height of the post from the post's base.

The weight of cable to use for each particular case should be determined by an engineer familiar with this construction after he has been given the length of the line, the weight to be supported, and the spacing of posts. The manufacturers of cables are prepared to recommend necessary size and kind of cable. It is well to use double galvanized materials, which will be lasting. The pipe is suspended from the cable with short lengths of about No. 14 galvanized wire spaced 15 to 18 feet apart. The nozzle line is hung in special galvanized-metal hooks containing rollers to make the pipe turn easily, and an eye for attaching to the suspension wire. The nozzle line can be graded by adjusting the lengths of the suspension wires.

The chief advantage in the suspension system is the reduction of obstruction in the field, and where it is well constructed the plant will be very durable. This type costs more than the others and is not as commonly used as the simple post supports. The cleaning of nozzles on highly supported lines is difficult, so the pipe should be kept within reach.

The pipe in the nozzle lines should be galvanized wrought iron or steel. The galvanizing not only makes the system longer lived, but reduces oxidation of the metal, which, if not prevented, tends to form scales that fill the nozzles.

A nozzle line is connected with the main feed pipe by means of a riser cut the proper length to act as the first post in the line. In the longer lines it is well to have the riser of 1½-inch pipe, which will make a strong support even if this is larger than the first section of nozzle line. An elbow is placed on top of the riser, and into this is screwed a long nipple which terminates in a standard brass gate

valve. To reduce friction this valve should be of the same size as the standpipe. The turning union is screwed into the opposite side of the valve. The union most commonly used contains a screen for catching sediment from the passing water. A capped handle 2 feet long, made of ¾-inch pipe, is screwed into the side of the union. This serves as a lever for turning the nozzle line in its bearing as well as giving entrance to the union for flushing the screen.

Reducing couplings and not bushings should be used for connecting the different pipe sizes. A ¾-inch valve or a cap should be placed over the extreme end of the nozzle line. This permits flushing out the line at any time by opening the valve or removing the cap.

There are several kinds of pipe adaptable for spray irrigation mains, steel, or wrought iron with threaded joints, riveted steel with flanged or bolted joints, cast iron with lead or bolted joints and wood-stave pipe.

Since the designing of an overhead system requires considerable engineering ability it is best to have experts do this part of the work. There are firms specializing in irrigation systems and these can furnish the plan and design.

CHAPTER XII

ROTATION, SUCCESSION AND INTERCROPPING

ROTATION

The term rotation as applied to crop production may be defined as a systematic arrangement for the growing of different crops in a more or less regular sequence on the same land. Crop rotation differs from succession cropping in that the former covers a period of years, 2, 3 or more, while the latter refers to the growing of two or more crops successively on the same land in 1 year. Systematic crop rotation is not as common in vegetable growing as in general farming. Rotation is, however, important in vegetable growing and should be practiced as systematically as possible.

Advantages of Crop Rotation.—Among the most important advantages of crop rotation are: (1) Aids in the control of insects and diseases; (2) equalizes the drain on the supply of raw materials in the soil; (3) prevents or reduces injury caused by poisonous substances in the soil; (4) utilizes more thoroughly farm manures, remains of previous crops and commercial fertilizers; (5) systematizes gardening and (6) keeps the soil in better physical condition than is the case in any one-crop system of farming. There are many other advantages that might be gained by crop rotation under certain conditions, but those mentioned are the outstanding ones.

Relation to Diseases and Insects.—Many important plant diseases can be controlled in a practical way by systematic crop rotation in which the host plant occupies the same land not more than once in 3 or 4 years. This method is effective mainly on those diseases, the spores of which live only a short time. Club root of cabbage and turnips can be controlled by keeping the land free of cruciferous plants for 2 years. Other diseases such as potato scab and onion smut cannot be controlled by ordinary rotation since the organisms responsible for these diseases live longer in the soil than the organisms responsible for club root. When a crop is seriously diseased it should be followed by other crops which are not attacked by the same disease.

Many insects can be kept in check by crop rotation and the same general principles should be followed as in a rotation for disease control. Some insects feed on only one crop, while others feed on a few closely related crops. In either case a suitable crop rotation will be found

of value, for if the host plants are not near at hand when the insects emerge in the spring many will perish before reaching them. This is especially true of insects which travel only short distances.

Relation to Mineral Nutrients.—Crops vary widely in their nutrient requirements. Some crops, utilize relatively large quantities of nitrogen, while others use relatively large quantities of phosphorus and potash. It is desirable to plan the rotation so as to have foliage crops followed by root crops, or crops grown for their fruit, such as tomatoes. Through rotation manures and fertilizers are more thoroughly utilized than where the one-crop system is followed. This is especially true where crops with different requirements are grown in the rotation.

Hartwell and Damon (67) have shown that there is a great difference in the influence different crops have on those which follow. While they have not shown conclusively what factors are responsible for these differences the amount of nutrients removed from the soil is undoubtedly one factor. They report the results of yields of onions in 1910 following sixteen different crops grown in 1908 and 1909. All of the crops were fertilized alike and the materials supplied 50 pounds nitrogen, 90 pounds phosphoric acid (P_2O_5) and 150 pounds potassium (K_2O) per acre in 1908. In 1909 the phosphoric acid was reduced to 60 pounds and the potassium to 120 pounds. In 1910 all of the plats produced onions and the same fertilizer was used as in 1909. The yields of onions following the miscellaneous crops as reported in Rhode Island *Bull.* 175 are given in Table XII.

Table XII.—Yields of Onions in Bushels per Acre in 1910 Following Miscellaneous Crops Grown in 1908 and 1909
(From *R. I. Bull.* 175)

Plat	Crop grown in 1908 and 1909	Total yield of onions per acre 1910	Plat	Crop grown in 1908 and 1909	Total yield of onions per acre 1910
85	Onions	289	94	Rye, spring	187
86	Potatoes	110	95	Timothy and redtop	515
87	Beets, mangels	72	96	Redtop	524
88	Turnips, rutabaga	99	97	Timothy	362
89	Cabbage	88	98	Clover, red and alsike	
90	Buckwheat	112		Squashes 1909	362
91	Corn	286	99	Clover, alsike	415
92	Millet, Golden	319	100	Clover, red	249
93	Oats	346			

It will be noticed that the yield of onions was low following mangel beets, cabbage, turnips, buckwheat, potatoes and rye and high following redtop, timothy and redtop, and alsike clover. The authors do not state what they think caused these great differences in yields, but give additional data which throw some light on the subject from the standpoint of nutrients removed by some of the crops grown in 1909. Table XIII (R. I. *Bull.* 175, p. 24) shows the amount of nitrogen, phosphoric acid and potassium removed per acre by the crops grown in 1909 prior to the growing of onions on the entire area.

Table XIII.—Nitrogen Phosphorus and Potash Removed by the Several Crops

	Nitrogen, lb.	P_2O_5, lb.	K_2O, lb.
Onions	49.4	13.5	30.3
Beets, roots and tops	85.4	11.2	80.3
Buckwheat (two crops)	80.4	21.8	82.6
Rye (two crops)	45.5	14.2	53.8
Redtop	27.5	11.7	57.3

It had been found that potassium was not deficient but that nitrogen and phosphorus were decidedly lacking in the soil where the onions were grown. The lowest yields of onions were produced following beets and buckwheat which removed the largest amount of the deficient nutrients and the highest yield of onions followed redtop which removed the smallest amount of nitrogen and phosphorus.

The yield of buckwheat did not follow in the same order as onions.

The authors state that it was not universally true that the crops which removed the largest amount of nutrients were the ones which had the most depressing effect on a succeeding crop.

In later work Hartwell, Pember and Merkle (60) studied the effect of crop plants on those which follow by growing the plants in pots in the greenhouse. Five crops were used: Buckwheat, mangels, rye, onions and redtop. Fertilizers were applied in super-optimum and optimum amounts and with the latter from which potassium, phosphorus or nitrogen was omitted. The authors conclude that "The divergent effect of crops on those which follow seems not to be attributable, at least principally, to differences in the amount of nutrients removed by the crops grown previously; that is the smallest yield may not occur after the crop which removed the largest amount of even the most needed nutrient."

The soil acidity was affected differently by the several crops and generally, the best yields of the onion, a plant which is sensitive to conditions accompanying acidity, followed the crops giving rise to the least acidity. These indications assume added importance because of the observed fact that the effects of the crops on those which follow were much less divergent if the soil acidity was reduced by liming.

Vegetable growers report various instances of reduced yields of some crops following certain plants. It is the belief among muck soil truckers that carrots have a depressing effect on onions, celery and lettuce. Cabbage is reported to depress the yield of corn, that is, the yield is lower following cabbage than when corn follows corn.

Relation of Rotation to Injurious Substances.—The benefits derived from rotation of crops cannot be accounted for entirely on the basis of the factors that have been discussed. Experiments conducted by the United States Department of Agriculture and by some of the experiment stations indicate that the roots of some plants give off substances which are injurious to themselves. These substances may or may not be injurious to other plants.

Hartwell, et al have pointed out that there is a difference in soil acidity following the growing of different crops and that this affects the yield of onions. While there is very little proof that plant roots exude toxic substances which injure vegetables the principle should be considered when planning rotation. The effect of crops on those which follow should be given consideration regardless of the cause or causes of the differences observed.

Order of Crop Rotation.—While it is impossible to outline a definite order of rotation that should be followed under all conditions it is desirable to observe the following: (1) Alternate shallow-rooted and deep-rooted crops; (2) follow crops which furnish organic matter with those which favor its rapid decomposition; (3) vary the crops in rotation as much as possible in respect to the kinds and amount of nutrients required, character of root growth and the time of year during which they occupy the soil; (4) allow as much time as practicable for the growing of soil-improving crops.

In many truck growing regions, where land values are not high, vegetables are often grown in rotation with general field crops. Clover or some other leguminous forage crop often precedes the vegetable crop in the rotation. Where farm crops are not grown, the rotation practice varies widely and in many instances no definite system is followed. When practicable it is desirable to plant a winter cover crop on all land under cultivation. In the South a summer cover crop of cowpeas, soybeans, or other legume often follows early vegetables and this is turned under in time for a fall crop.

The vegetable grower must take into consideration the profits derived from various crops and the suitability of his soil to the production of different crops in planning his rotation. Under all conditions it is wise to avoid growing one crop on the same land for several years.

SUCCESSION CROPPING

Succession cropping is the growing of two or more crops successively on the same land in one season. For success this requires heavy fertilization and good cultural practices. On high-priced land it is necessary to keep the land occupied with a money crop a large part of the year and, by planning the cropping system carefully, two, three or four crops may be grown on the same land in one season. The kind and number of crops to be grown are determined largely by the length of the growing season and the markets to be supplied. In planning for a succession of crops the same principles should be considered as in planning a rotation system. As examples of succession cropping the following might be mentioned: (*a*) Early lettuce followed by snap beans, or root crops such as beets and carrots. In many sections the crop of beans may be followed by fall turnips or spinach; (*b*) early cabbage followed by late potatoes, where the growing season is long enough; (*c*) early potatoes followed by late cabbage; (*d*) early carrots followed by beans, late cabbage or late celery; (*e*) early lettuce followed by late celery. This is a very common practice on muck lands in some sections of the North. All kinds of combinations may be worked out but each grower must plan his own system to meet his needs. He should plan in advance in order to be able to utilize his land and labor to best advantage. In all cropping systems the distribution of labor through the season should be considered carefully.

INTERCROPPING OR COMPANION CROPPING

When two or more crops are grown together on the same land the system is known as intercropping or companion cropping. This may embrace succession cropping as in the planting of cabbage, lettuce and radishes at the same time. The radishes will mature and be removed first and then lettuce will follow. Both will be out of the way before the cabbage needs all of the space. Intercropping is followed mainly by intensive market gardeners where most of the work is done by hand. Foreign gardeners are more likely to follow this system than are American gardeners.

Advantages and Disadvantages.—The main advantages are: (1) Economy of space, which is important on high-priced land; (2) saving in tillage, as the same plowing, harrowing and cultivating serve for two or more crops; (3) better utilization of mineral nutrients, the surplus

applied to one crop being used by the other; (4) increased profits from the area cultivated.

The main disadvantages of intercropping are: (1) Increased amount of hand labor; (2) larger demand for mineral nutrients and moisture; (3) greater difficulty encountered in spraying for insects and disease. There is also danger of injuring one crop when another is being harvested.

For intercropping to be successful an abundant supply of labor must be available and there must be a liberal supply of manure. It is not practicable, under most conditions, where land values are low and labor high because large implements cannot be used successfully under most kinds of intercropping.

In planning for intercropping the grower should consider the time each crop is to be planted, the time each is to mature, the habit of growth and the amount of space each crop needs at various stages of growth. The supply of moisture and mineral nutrients in their relation to maturity should also be considered. Where irrigation is practiced, intercropping is more likely to be successful than where no provision is made for artificial watering.

Examples of Intercropping.—Various plans of intercropping are used by market gardeners. In nearly all plans small growing, quick maturing crops are planted with larger and later maturing crops. One common plan is to plant lettuce between the rows of cabbage plants and also between the plants in the row. The lettuce plants are usually started in the greenhouse or hotbed and mature in 5 to 6 weeks after setting in the field. Up to this time the cabbage plants do not require more than half of the space given. Another plan includes radishes, which are planted between the cabbage and lettuce rows. Radishes and carrots are often grown together, the former being planted between the rows of the latter. Cabbage and tomatoes are often grown together, early cabbage plants being set early in the season and tomatoes set between the rows. The rows of cabbage plants are spaced farther apart than under single cropping. Intercropping is commonly practiced in new asparagus beds and in all kinds of fruit plantings. In this way the land produces money returns, before the perennial plants reach bearing age. The grower should at all times consider the welfare of his perennial plants in any system of intercropping. The land should be well fertilized in order to provide for both crops, and the perennial plants should not be crowded.

CHAPTER XIII

CONTROL OF DISEASES AND INSECTS

Knowledge of control measures for important disease and insect pests is fundamental to successful vegetable growing at the present time. Both diseases and insects are becoming more serious due to the more intensive methods of gardening and the bringing in of new pests from foreign countries. No subjects, taught in agricultural colleges, are more important for the student interested in vegetable gardening than entomology and plant pathology. Not only should the student learn the methods of control but he should be able to recognize common insects and diseases in the field. Essential points in the life history of common organisms should be known in order that control measures may be applied intelligently.

Since practically all agricultural colleges are giving fundamental courses in entomology and plant pathology these subjects are considered here only in their general relation to vegetable production.

Importance of Controlling Pests.—Insects and plant diseases cause losses to the vegetable growers of the United States running into many millions of dollars, probably into the hundreds of millions. Exact estimates are impossible because there are so many factors involved. To estimate the percentage of crops destroyed and then figure the monetary loss at the average price received for the portion saved is entirely misleading, because a reduction in total yield nearly always has the effect of increasing the price. In other words, a short crop often brings a greater total return, as well as a larger net return than a very large yield. However, if insects and diseases did not have to be considered, vegetable growers could more accurately plan their plantings to meet the consumers' needs. They now make allowances for probable losses due to insects and diseases, and when these pests do not cause as great damage as expected there is usually a large yield, and this results in low prices. If, on the other hand, the losses are greater than normal the crop yields are low and this results in high prices to the consumer. In the long run the losses due to insects and diseases must be borne by society. The cost of production is greatly increased by diseases and insects because of the reduced yield due to their ravages. The expense of control measures practiced also adds to the cost to the consumer. With some vegetable crops the treatment for diseases and insects is one of the largest items in the cost of production. This item alone adds millions of dollars each year to the

cost of food. There is also loss due to reduction in quality, for vegetables that are badly injured by insects and diseases are inferior to those that are not injured.

Up-to-date vegetable growers recognize that in many instances spraying, dusting and other control measures are just as essential as cultivation or any other operation. It is impossible to produce satisfactory crops of certain vegetables in many regions without measures being taken to control diseases or insects or both. Even when diseases are not so serious as to be very evident on casual inspection of the field it has been found that spraying or other treatment has in many instances greatly increased the yield. Instances are on record where the yield of celery was increased by 60 crates per acre by spraying for blight, although the growers stated that their crops were not blighted. Onion yields have been increased 200 to 400 bushels per acre through smut treatment where the growers claimed that their crops were not seriously injured by this disease. Many other illustrations might be given but these show the importance of knowing what injury is being done by diseases and insects. Wherever crops are being injured by pests it is desirable to try out control measures to see if the value of the products is sufficiently increased to justify the expense of the treatments given.

Methods of Control.—Among the means of controlling insects and diseases the following are important:

1. *Rotation of Crops.*—The importance of crop rotation in insect and disease control is discussed in Chapter XII.

2. *Destruction of Refuse Harboring Diseases and Insects.*—Insects of many kinds pass the winter in the refuse left on the field or garden. If this is plowed under most of the insects will perish, but in case of diseases, which live over winter on the plant remains, plowing does not destroy them. Some insects also pass the winter in weeds and trash in the fence rows and around the edges of the field; therefore cleaning up these places is of importance.

3. *Fall Plowing.*—In regions where severe freezing occurs many insects are destroyed by exposing the larvæ or hibernating adults to the weather by plowing the land in the fall. The exposure to changing weather conditions even without severe freezing destroys many insects which pass the winter in the soil. The disease caused by the nematode, an animal parasite, is not serious in the gardens of the North (but is a pest in greenhouses) because the severe freezing of the soil kills the parasite.

4. *Destruction of Affected Plants.*—This is an aid in the control of some diseases, such as bacterial wilt of cucumber and melons by preventing the spread of the disease. Destruction of insects, which feed on the plants is also important since they spread the disease.

5. *Abandoning for Two or Three Years Any Crop Badly Affected by Pests.*—This may be cheaper and quicker than to try to destroy the pest.

Club root of cabbage and cauliflower can be controlled in this way provided no crop affected by this disease is grown on the land for two or three years.

6. *Protecting Plants by Mechanical Means to Prevent Insect Ravages.*—The most common method is to exclude the insect by screening the plant or seed bed. Individual plants and hills of cucumbers and melons are often covered with cheese cloth tacked on a frame or with a cone-shaped screen made of wire netting to protect the crop against injury by the cucumber beetle. Screening the late cabbage seed bed with cheese cloth prevents injury by the cabbage maggot. The screen prevents the fly from depositing eggs on the seedlings, or on the soil.

7. *Use of Trap Crops in Controlling Insects.*—The harlequin cabbage-bug can be kept in check by planting kale, mustard, or rape so that the plants will be available to the insects before the desired crop is up. The bugs will congregate on the trap crops where they may be killed by spraying with pure kerosene. In the fall a few plants of turnips, cabbage or kale left in the field after the main portion of the crop has been harvested, will attract the bugs which may be killed before going into hibernation.

8. *Seed Treatment to Control Insects and Diseases.*—Seed potatoes are treated with corrosive sublimate for potato scab and rhizoctonia. This treatment destroys the organisms on the surface of the tubers. Formalin is also used for potato scab. Treatment of cabbage seed with corrosive sublimate and with hot water is recommended for black-leg. Seed treatment is of little avail if the soil in which the treated seeds are to be planted is infested with disease organisms.

Bean and pea weevils can be kept under control by treating the dry seed with carbon disulfid. To be most effective the treatment should be made in the fall soon after the harvest since the insects develop in the dry seeds.

9. *Soil Sterilization.*—Diseases in plant beds and in vegetable forcing houses are kept under control by sterilizing the soil by means of steam or formalin. Steam, when properly used, kills insects and weed seeds in the soil as well as diseases. The methods of steam sterilization commonly used are the steam box, the inverted pan and the perforated pipe. Soil for seed boxes is often sterilized in a steam box, but this method is not very practicable where a large quantity is to be treated. By the inverted pan method a large galvanized pan (6 by 10 feet) about 6 inches deep is pressed down over the soil to be sterilized. The pan is connected to a steam boiler by means of pipe or rubber hose. In the perforated pipe method 1¼- or 1½-inch pipe, with ¼-inch holes on the under side at intervals of 12 inches is placed in the soil 8 to 12 inches deep. The lines of pipes should be about 18 inches apart and connected to a steam boiler. The soil should be heated to near the boiling point and kept

there for 1 to 2 hours. A few potatoes placed on the surface of the soil will indicate the thoroughness of the treatment. When the potatoes are cooked the soil is well sterilized.

10. *Fumigation.*—This is a common method of controlling insects in the greenhouse. Various kinds of tobacco preparations, sulphur and hydrocyanic acid gas are the most common fumigants. The last mentioned is a deadly poison which will kill all kinds of animal life; therefore it should be used with the utmost care.

11. *Use of Repellants.*—Plants are sometimes protected from insect injury by means of materials which repel the pests. Slaked lime, dry ashes, dust and other similar substances are often used to repel cucumber beetles. Bordeaux mixture is used for protecting plants against flea beetles, the foliage being thoroughly coated with the material. Tarred paper discs are sometimes used around cabbage plants to prevent the adult of the cabbage maggot from depositing eggs on the plant. The repellants do not destroy nor injure the insects, but prevent them from attacking the plants.

12. *Killing Insects and Preventing Disease Injury by Spraying and Dusting.*—Insects are classified into: (1) Chewing or biting forms, which devour the leaves and other parts of the plants; and (2) sucking forms which injure and destroy plants by sucking their juices. For biting or chewing insects stomach poisons are used, arsenicals being the most common. For sucking insects contact poisons, such as kerosene emulsion and tobacco sprays are used.

Many fungous diseases are controlled by spraying the plants with a mixture poisonous to the fungus but harmless to the plant. In spraying for disease control the material should be applied before the disease appears, for most treatments prevent the development and spread of the fungus rather than destroy it after it has once secured a foothold on the plant. Spraying before a rain is preferable to applying the material after a rain, since the spores germinate best under moist conditions. Of course, the spray material should be applied far enough in advance to allow it to dry before rains.

Timeliness and Thoroughness.—In all insect and disease-control measures timeliness and thoroughness are important considerations. For instance the fungicide should be applied before the appearance of the diseases or at least as soon as there is the slightest evidence. It is too late to control diseases after they have seriously injured the crops. Even for insect control, treatment is most effective when the material is applied as soon as the insects make their appearance. If the treatment is delayed too long the plants may be seriously injured or killed before the insects are destroyed. This is especially true where there is a heavy infestation, as there may be so many insects present as to do considerable damage before getting enough poison to kill them.

Since insects are killed either by eating the poison, or by coming into contact with it and disease spores are killed or inhibited by contact with the fungicide, it is important to cover all parts of the plant with the material. For many diseases and insects the underside of leaves, as well as the upperside, should be covered. Spray materials should be applied as a fine mist so as to cover the surface thoroughly without having the liquid collect in drops and run off. To get a fine mist high pressure is necessary even with the best of spray nozzles.

Spray Pumps.—Various kinds and sizes of sprayers are on the market, from the small hand atomizer to the large power sprayers. The small sprayers are not as efficient nor as economical as the large ones so that commercial gardeners should secure the largest one that is practicable for the acreage to be sprayed. Under most conditions nothing smaller than the barrel sprayer should be purchased by the commercial grower. Power sprayers are generally used for such crops as potatoes and celery. Some of these get their power from gearing the pump to the axle of the sprayer, while others are equipped with gasoline engines. Where high pressure is important the engine-driven pump is preferred.

Insecticides.—There are three general types of insecticides, stomach poisons, contact poisons and repellants. Stomach poisons are used to destroy biting insects such as potato bugs and cabbage worms. Contact poisons are used in killing sucking insects, such as plant lice and squash bugs. Repellants, as lime and tobacco are used to protect plants from injury from insects which are not readily killed. The repellants do not kill the insects but are often effective as deterrents. Bordeaux mixture is sometime used as a repellant for flea beetles.

Arsenate of Lead and the Arsenicals.—Arsenate of lead is the most valuable and usually the cheapest of the stomach poisons. It is less likely to injure foliage than Paris green; it adheres better and remains longer in suspension. Arsenate of lead is available in either powder or paste form. Two pounds of powder or 4 pounds of paste to 50 gallons of water is the usual recommendation. The lead may be used with Bordeaux mixture without reducing the effectiveness of either. Arsenate of lead powder may be applied dry by mixing it with slaked lime or other fine dry material in the proportion of 1 part of the lead powder to 5 to 10 parts of lime or other material. To be most effective this should be applied when the foliage is damp.

For years in many regions powdered arsenate of lead and Paris green have been used in the dry form for the control of the Colorado potato beetle and other chewing insects. With the manufacture of power dusting machines a great impetus has been given to the use of arsenicals and other insecticides in dust form. Results of experiments in Virginia, as reported by Zimmerly, Geise and Willey (190) show that thorough dusting of potato plants with 20 per cent calcium arsenate dust at the rate

of 20 pounds to the acre resulted in perfect control of the larvæ of the potato beetle. In their experiments with dust for the control of the cabbage looper and the imported cabbage worm on kale and Brussels sprouts a mixture of 50 per cent calcium arsenate and a material called Noburn (a material containing about 23 per cent arsenious oxide, derived chiefly from Paris green) gave equally good control. They state that the action of Noburn was more rapid than that of calcium arsenate.

Tobacco Preparations.—Nicotine, the poisonous principle of tobacco is a powerful contact insecticide. It is now widely used in the form of nicotine sulphate and may be purchased under this or other trade names such as "Black-Leaf 40." For plant lice and other soft-bodied insects, nicotine sulphate is diluted with 800 to 1,000 parts of water. A common spray formula is $\frac{3}{8}$ pound of nicotine sulphate (40 per cent) and 2 pounds of soap to 50 gallons of water. This gives 1 part nicotine sulphate to 1,000 parts of water. The soap is used largely as a sticker and adds to the effectiveness of the material. Any of the tobacco preparations can be combined with Bordeaux mixture without decreasing the efficiency of either material.

Nicotine is used also for fumigating greenhouses to destroy insects either by smudging with moist tobacco stems, various kinds of punks and papers containing nicotine, or by evoporating a nicotine extract.

Tobacco dust has been used as an insecticide for a long time. but it is only within recent years that the prepared material containing nicotine has been used in dust form for insect control. The carrier most commonly employed is hydrated lime. Experiments with this material have been carried on by several investigators. Parrott (113) has reported on results secured in controlling the cabbage aphis. He found that an application of 20 pounds of a 2 per cent nicotine preparation to the acre was the most satisfactory from the standpoint of economy and effectiveness.

Zimmerly, Geise and Willey (190) tested various carriers of nicotine including hydrated lime, kieselgur and kaolin and they all proved of equal value for aphis control. Lime is the cheapest and is therefore recommended. They also tried various percentages of nicotine and found that the 3 per cent dust proved most effective in the control of spinach aphis, the pink and green aphis, the cabbage aphis and the melon aphis. In the laboratory the 1, 2 and 3 per cent nicotine dusts killed 72.2, 82.1 and 89.3 per cent respectively, based on the average for the four species. They state that for the control of the spinach aphis and the pink and green aphis on spinach, a hydrated lime carrier with 2 per cent nicotine-impregnated dust proved the most economical. The quantity necessary varied from 20 to 40 pounds to the acre.

Fungicides.—The term fungicide is applied to any material used to control fungous diseases. Bordeaux mixture is the most common fungi-

cide used as a spray for vegetables. Dry Bordeaux is being used to a limited extent for diseases of some vegetable crops. Formalin, corrosive sublimate and sulphur are also used as fungicides but these are not usually sprayed on the plants.

Bordeaux Mixture.—The most common formula for making Bordeaux mixture for spraying vegetables is 4 pounds of copper sulphate, 4 pounds of stone lime to 50 gallons of water. This is known as the 4–4–50 formula. A stronger mixture is made by using 5 pounds of copper sulphate and 5 pounds of lime to 50 gallons of water.

Where Bordeaux mixture is to be used in large quantities it is desirable to make up stock solutions by dissolving 50 pounds of copper sulphate in 50 gallons of water so that a gallon of the liquid will contain 1 pound of copper sulphate. If more convenient, 100 pounds of copper sulphate may be dissolved in 50 gallons of water in which case each gallon of solution will contain 2 pounds of copper sulphate. Stock lime mixture may be made up by slaking 50 or 100 pounds of lump lime in a barrel and adding a definite amount of water so that a gallon of the solution will contain a known amount of lime. In case hydrated lime is used increase the amount to 6 pounds for each 50 gallons of Bordeaux mixture.

To make Bordeaux mixture of the 4–4–50 formula from the stock solutions the sprayer is usually filled about three-fourths full of water and 4 gallons of the copper sulphate solution is added to every 50 gallons of the mixture to be made. The stock solution should be stirred before being taken out and the water in the sprayer should also be agitated after adding the copper sulphate. The lime solution is then added, using enough to give 4 pounds of lime to each 50 gallons of the mixture. The lime-water should be run through a strainer in order to prevent the large particles of lime from getting into the sprayer tank. While pouring the lime solution into the sprayer the material in the tank should be stirred constantly. Water is then added to fill the tank.

To test the mixture dissolve a few crystals of potassium ferricyanide in a pint of water and pour a few drops into the Bordeaux. If a brown-colored precipitate forms more lime is needed to neutralize the copper-sulphate. Bordeaux mixture not properly neutralized will burn the foliage of plants.

Copper-lime Dust.—Within the past few yearsthe use of copper-lime dust has been highly advertised by companies manufacturing fungicides and many of the experiment stations have undertaken experiments to determine its effectiveness in disease control. While much less experimental work has been done to determine the value of this dust for vegetable diseases than for fruit diseases, it has been used on potatoes, celery, cucumbers and other vegetables. Results secured in controlling celery blight in New York indicate that copper-lime dust, properly applied, gives practically as good control as liquid Bordeaux mixture.

However, the use of dust, as a fungicide, has not passed the experimental stage and is not generally recommended.

The copper-lime dust is used in the proportion of 15, 20 and 25 parts dehydrated copper sulphate to 85, 80 and 75 parts of hydrated lime as a carrier.

Corrosive Sublimate (Mercuric Chlorid).—One ounce of corrosive sublimate to 7½ or 8 gallons of water makes an effective fungicide for treating potatoes and sweet potatoes for diseases on the surface of the seed and is an effective insecticide for cabbage maggot. This material is a deadly poison and should be used with the greatest of care. Corrosive sublimate solution should be used in wooden or stone vessels as it reacts with metal and thereby looses strength.

Formalin.—This is a commercial preparation containing about 40 per cent formaldehyde gas in water. One pint to 30 gallons of water is the formula usually used for treating potato tubers. For sterilizing soil 1 part formalin to 50 parts of water is considered the best, although a weaker solution (1 to 75 or 1 to 100) is sometimes recommended.

General Crop Diseases.—Among the more serious diseases that are rather general, the most important are root-knot, caused by a parasitic eelworm or nematode; Rhizoctonia which causes cankers on the stems and roots of various plants; and damping-off. Root-knot is discussed in connection with cabbage, Chapter XX, and Rhizoctonia is described in Chapter XXIII in connection with the potato.

Damping-off is often serious on plants in the seed bed and transplanting bed. The plants are attacked at or near the surface of the ground causing a rotting or "damping off." This may be caused by any one of several species of fungi including Pythium, Rhizoctonia, Botrytis, Sclerotinia, Phoma, Phytophthora, Colletotrichum and Gloeosporium.

Since the growth of these fungi is favored by moisture and relatively high temperature, the trouble may be checked by keeping the temperature down and withholding water. It is especially important to water the plants in the bed early in the day so that the plants themselves and the surface of the soil may dry before night. Thorough ventilation of the greenhouse, hotbed and cold frame is important.

Sterilizing the soil used for the plant bed by means of steam or formalin will destroy the fungi if the work is done thoroughly.

General Crop Insects.—Insects may be grouped roughly into two classes, from the standpoint of their food plants: (1) Those which ordinarily attack only a single crop, or a few closely related crops, and (2) those which are general feeders and are not particular as to their food plants. Examples of the first class are asparagus beetles, potato beetle and the large tomato worm, the last two feeding on a few closely related plants. The second class includes cutworms, white grubs, wireworms, blister beetles, grasshoppers, onion thrips, and red spider.

The onion thrips is usually most injurious to the onion crop although it attacks cauliflower, cabbage, cucumbers, tomatoes, turnips and kale. This insect is discussed in connection with the onion crop. The other insects are discussed here because they are equally destructive to a number of crops.

Cutworms.—Cutworms are nearly smooth caterpillars 1 to 2 inches long, the larvæ of large-bodied moths. Many species have been reported as pests of vegetable plants. Their greatest injury is done by cutting off the stems of young plants near the surface of the ground, especially to those plants which are transplanted and are spaced considerable distances apart, as cabbage, cauliflower, tomato, eggplant and sweet potato. Cutworms work mainly at night and one worm can destroy many plants in a single night.

The best method of control is the use of poisoned baits. A common bait is made with the following materials:

Bran	20 pounds
Arsenate of lead powder	1 pound
Molasses	2 quarts
Oranges or lemons	3 fruits
Water	4 gallons

The dry materials are mixed thoroughly in a tub or other receptacle. The juice of the oranges or lemons is squeezed into the water and the molasses is also mixed with the water, then a mash is made. After the mash has stood for a few hours, it is scattered over the field in small lumps. It should be put out late in the day so that it will not dry out before night. The bait should not be used where there is danger of chickens getting it.

Clean cultural methods and fall plowing also aid in controlling cutworms.

White Grubs.—These are the larvæ of May beetles or June beetles (*Lachnosterna arcuata*). They feed chiefly on the roots or other underground portions of the plants and are often injurious to corn, potatoes, and strawberries, but they are general feeders. Grubs are usually most injurious to crops following sod.

A short rotation in which sod is left not more than two years is advised. Clean culture and plowing in the fall aid in the control of this pest. Hogs and chickens, if allowed the run of newly plowed land, destroy large numbers of the grubs. Where they are abundant in sod land it is best not to use it for potatoes or sweet corn.

Wireworms.—Wireworms are the larvæ of click beetles. They are long, hard-shelled, brownish larvæ often abundant in sod land. They are injurious to the roots and other underground portions of the plants, especially to potatoes, carrots, beets, sweet potatoes and onions.

The remedies advised for white grubs apply to wireworms, but they are much more difficult to control.

GRASSHOPPERS.—These insects are quite troublesome to vegetables, especially in the dry regions of the Middle West. Poisoned bait as recommended for cutworms is one of the best remedies for grasshoppers.

BLISTER BEETLES.—These insects are common garden pests and are often destructive to beans, peas, potatoes and beets, although they feed on many kinds of plants. The beetles are slender, somewhat soft bodied and variously colored. They are injurious in the adult stage and are difficult to control.

Spraying with arsenicals when the beetles first appear is the best remedy.

RED SPIDER.—The red spider (*Tetranychus telarius*) is not a true spider but a mite. It is well-distributed and is often injurious on beans of all kinds, eggplant, cucumbers and other cucurbits, tomatoes, beets and celery. It is a serious greenhouse pest. It is often present on the underside of leaves without being suspected. It injures the plants by sucking the juices. When abundant, the leaves lose their color, shrivel and die.

Spraying with "Black Leaf 40" or other nicotine preparation is the best remedy for red spider in the open. In the greenhouse, spraying the plants with water under pressure will reduce the number of red spiders, and is the method of control commonly employed.

CHAPTER XIV

MARKETING

Profits in commercial gardening depend as much upon proper handling and marketing as upon good cultural practices. Many gardeners, however, assume that when they have produced crops of good quality and put them on the market they are not to blame if the receipts do not cover cost of growing. The grower is largely responsible for the appearance of his product when it reaches the market, and, unless he has carefully graded and packed it in attractive, substantial packages, he has not done all that is expected of him. The essentials for success in profitable marketing are: (1) A good, seasonable product; (2) careful and uniform grading; (3) good packing; (4) attractive packages; and of convenient size and shape for the product; (5) judicious selection of markets to avoid gluts; (6) honesty in grading and packing and in all dealings with the buyer and (7) good salesmanship.

Many gardeners are experts as producers and failures as salesmen. This is natural since the problems are different, but it is essential that the grower, who does his own marketing, devote time and study to the problems of marketing as well as to those of production. Under many conditions it is probably better for the grower to specialize on production and let others do the marketing than to attempt to become expert in both lines. However, the grower must know what the market demands both in products and methods of handling, even if others are looking after the selling.

Much of the marketing problem belongs to the field of economics and hence will be discussed here very briefly. To understand the problems of transportation, of organization of marketing associations and of merchandizing requires a knowledge of the fundamentals of economics.

Harvesting.—The stage of development of vegetables when harvested determines to a considerable extent the quality of the product when it reaches the consumer. No definite rule can be given in regard to time of harvesting since this depends upon the kind of crop, the weather conditions at harvest time and the distance to market or the length of time required to reach the consumer. Some crops as beans, lima beans, peas, sweet corn, etc. deteriorate in quality if not harvested soon after reaching edible maturity; therefore it is always advisable to harvest

as soon as this stage is reached. With products which increase considerably in size after reaching edible maturity there is a tendency to delay harvesting until they have reached full size. This delay often results in lowering the quality of the product, especially with beans, peas, lima beans, beets, carrots, cucumbers and sweet corn. Tomatoes and muskmelons grown for distant markets are harvested long before they reach edible maturity. In fact, in many cases they have not begun to ripen when harvested. This results in poor quality and has a decided tendency to depress the market for these products. Both tomatoes and muskmelons should be allowed to remain on the vines as long as possible and still have them reach the consumer in good condition.

Promptness is of great importance in harvesting and handling many perishable crops. A day's delay may result in heavy losses, especially in hot, sultry weather or in seasons when frosts are likely to occur. Lettuce often becomes almost worthless in a day after the heads have formed, especially if the weather is very hot. The plants may send up seed stalks or become seriously injured by "tip burn" and "drop." Promptness in removing the products from the field is important with most crops, especially in very hot weather and in wet weather.

Enormous losses occur each year due to carelessness in harvesting and handling vegetables. Much of this could be overcome through instruction of the help in the proper methods of harvesting and handling the products in the field. Bruising or other injury detracts from the appearance of the product and makes it more susceptible to disease injury, since germs are more likely to get a foothold if the surface is broken.

Preparation for Market.—Many vegetables require special preparation before they are ready for packing. Root crops, asparagus, celery, lettuce, spinach and other vegetables are often washed to remove any soil that adheres. While water is used mainly for the sake of cleanliness it has other values. It gives some vegetables a bright appearance and prevents them from wilting. Washing may be injurious, since moisture on the surface is favorable to the development of diseases, especially when the washed product is packed tightly and shipped considerable distances. Ridley (123) found that washing spinach increased decay and recommends that it be shipped unwashed, unless it is very dirty.

Some vegetables are trimmed in preparation for marketing. The dirty, decayed, diseased and discolored leaves of celery, lettuce, spinach and other leafy vegetables are removed before the products are packed for market. Removing diseased leaves is of value in checking the development of disease in transit and on the market, and also improves the appearance of the product. Ramsey and Markell (120) found that removing lettuce leaves which rested on the soil reduced the loss due to the development and spread of lettuce drop (*Sclerotinia libertiana*) in transit. Part of the foliage of root crops and onions, when bunched

for market, is removed either by stripping off part of the leaves or by cutting back all of them. In any trimming the aim should be to improve the appearance and otherwise increase the value of the product.

Asparagus, rhubarb, celery, green onions, early beets, and carrots are often tied in bunches in preparation for market. This is done for convenience in handling in retail stores. Various materials such as raffia, common wrapping cord and special tape are used for tying. The bunches should be tied tightly so that they present a neat appearance on the market.

Grading.—Well-graded products of inferior quality often sell to better advantage than poorly graded or ungraded products of high quality. A few inferior specimens in a package govern, to a considerable extent, the price paid for the entire contents of the package. Uniformity in size, shape, color and ripeness is of great importance in disposing of any product and this cannot be secured without careful grading. Grading means more than separation with reference to size, although this is important. In separating any product into grades all characters that affect the appearance and quality of the product should be considered.

Not only should vegetables be carefully graded, but there should be some recognized standard that applies to a region or preferably to the whole country. Uniform and well-recognized grades make for cheap marketing, for, if articles are not graded or are poorly graded the buyer has to inspect the product before he can know what he is buying. This adds to the cost. By dividing products into uniform grades, sales may be made by sample, or even by description, thus facilitating the marketing process. Uniformity in grading is absolutely essential to success where products are sold on grade.

Standard grades furnish the basis for trade. Some standard is essential in marketing products at a distance, and also for market information and inspection. Lack of grade standards has made market quotations unsatisfactory to the grower because it has not been possible to describe products in terms that are understood. With standard grades the buyer and seller have a common language in the grade name or number. This is especially true if the grades are legalized by state or national laws. The purchaser of potatoes under the U. S. Potato Grading Law is reasonably sure that he will get a product that will meet at least the minimum requirement of the grade specified, and the grower is reasonably certain to secure a price based on a definite grade. Standard grades eliminate a great deal of friction between producer and dealer due to lack of understanding and also reduces loss caused by rejections, delays and dishonest dealing. They simplify the whole marketing process. Standardizing grades is one of the first improvements attempted by any successful cooperative marketing organization, for it is recognized that the first step in marketing is to have standard products.

During the past 10 years the United States Department of Agriculture and some of the states have studied the methods of grading employed by the most successful producers and dealers with the idea of working out grade standards for various products. The fact that definite grade standards have been recommended for only a few products indicates the care that is being taken in working out this problem. The Bureau of Markets of the U. S. Department of Agriculture, after several years' study, has suggested tentative grades for tomatoes, cabbage, sweet potatoes, northern-grown onions, Bermuda onions, celery, cucumbers, lettuce and asparagus. If these grades meet with approval of the grower and dealer, after sufficient trial, Congress will be asked to legalize them.

In any set of grade standards the aim should be to make the grading and the descriptive terms as simple as possible. Technical descriptions and complicated grades discourage the use of any set of standards by the average grower. The number of grades should be kept to the minimum, preferably only two for most products. The first grade should include a large part of any well-grown crop. The second grade should usually include the marketable product that does not meet the requirements for the first grade. If any portion of a crop is below the requirements of the second grade, and is still marketable, it should ordinarily be sold by sample as "sample grade."

Packages for Vegetables.—Packages of some kind are necessary for nearly all vegetables when they are shipped, and for most of them even when hauled direct to the market from the field. Packages perform the following functions: (1) Furnish convenient means for hauling products; (2) give protection to the goods themselves; (3) furnish security from pilfering; (4) provide a measure of the contents; (5) provide ventilation; (6) prevent loss of small articles; (7) insure cleanliness; (8) provide a means whereby products may carry identification marks, shipping directions, legal requirements and advertising matter.

Vegetables are packed in various kinds and sizes of packages from the small berry box to the barrel, including all kinds and sizes of baskets, hampers, boxes, crates and bags. Downing (38) writing on this point states, that there are in common use today (1921) about 40 sizes of cabbage crates, 20 styles of celery crates, 30 styles of lettuce crates or boxes, 50 styles and sizes of hampers, 15 styles and sizes of round stave baskets and market baskets varying in size from 1 quart to 24 quarts, whereas relatively few standard sizes would satisfy all the demands of the trade.

The above statement shows the need for standardization of packages and the elimination of a large percentage of the sizes and styles now in use. The large number of types and sizes of packages in use make for confusion and add to the expense of the product by increasing the machinery necessary for manufacture. Lack of standardization of packages, with reference to size, makes it easy for dishonest persons to give short

measure. Many packages, which appear to have the same capacity, often show a difference of 10 to 25 per cent or more in actual measure-

FIG. 4.—Two hampers of similar appearance but of different capacity. The pile of beans in front of the basket on the right represents the difference in quantity held by the two baskets.

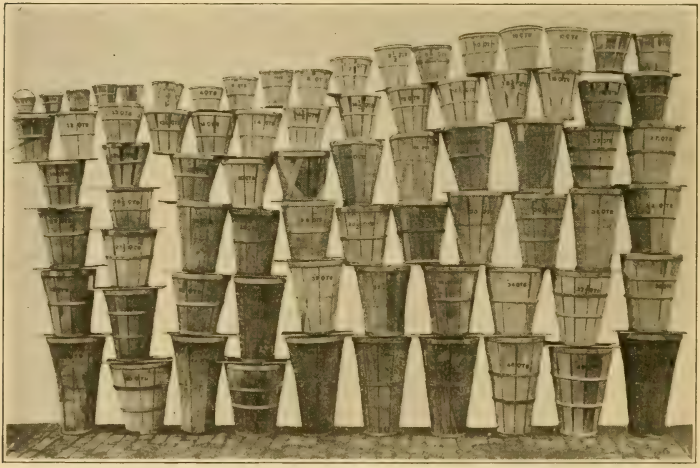

FIG. 5.—Seventy-five types and sizes of hampers in use in the United States in 1920. Compare with Fig. 6. (*Courtesy of U. S. Department of Agriculture.*)

ment (Fig. 4), due to slight difference in one dimension. This is noticeably true of the hamper, which is made in sizes ranging from one quart to

48 quarts. Figure 5 illustrates the various sizes and shapes of hampers found on the market, and Fig. 6 shows five which would meet all of the requirements.

Fig. 6.—Five hampers of sizes and types recommended by the U. S. Department of Agriculture, as meeting all the requirements of the trade. Compare with Fig. 5. (*Courtesy of U. S. Department of Agriculture.*)

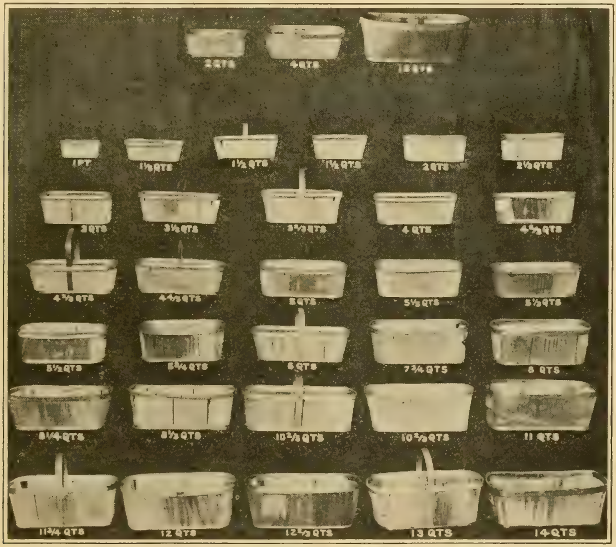

Fig. 7.—Above: Till or small fruit baskets now standardized by law. Below: Some of the sizes of small fruit baskets before Government standardization. (*Courtesy of U. S. Department of Agriculture.*)

Standards for containers for fruits and vegetables have been established by the Federal Government for the standard barrel, containing 7,056 cubic inches, and its subdivisions; the cranberry barrel, containing

5,826 cubic inches with its subdivisions; three standard sizes of Climax grape baskets (Fig. 7), containing 2, 4 and 12 dry quarts, respectively; and standard berry boxes and till baskets, containing one-half pint, pint, quart and multiples of the quart, dry measure. The Standard Barrel Act is enforced by the Bureau of Standards, Department of Commerce, and by local sealers of weights and measures in those states which have adopted the Federal Standard. The United States Standard Container Act, fixing standards for Climax baskets and for berry boxes, and small till baskets, is enforced by the Bureau of Markets of the Department of Agriculture.

The hamper is one of the most widely used shipping containers and is well adapted to light produce. It is not entirely satisfactory for heavy produce, especially for the tomato which is likely to be injured by being crushed. The fruit in the bottom of a hamper is often badly crushed by the weight of the fruit above. The main advantages of the hamper are: (1) Relatively low price; (2) lightness in weight; (3) convenience in handling and transporting when empty since they nest well; (4) provide good ventilation and(5) allow good circulation of air when loaded in a car.

Round stave baskets are popular in many regions and are increasing in popularity. These baskets are used to some extent for cauliflower when hauled direct to market, and for beets, carrots, sweet potatoes, peppers, beans and peas. Round stave baskets are used for shipping vegetables and are also used in the field in the place of lug boxes.

Splint or veneer baskets, commonly known as market baskets, are used extensively in marketing greenhouse products, such as lettuce, tomatoes and cucumbers. These baskets are also used to a large extent as direct marketing packages, because they can be carried conveniently, thus encouraging the purchase of produce in larger quantities than is usually the case.

Boxes and crates of various styles and sizes are used for many products. Most of these are made for a specific product as lettuce boxes, celery crates, cauliflower crates, asparagus crates or boxes and muskmelon crates. Some of these crates and boxes, such as the folding crate and the lug boxes, the latter used largely in local marketing, are employed for many products. Lug boxes are not made for any particular product, but for use in hauling all kinds of vegetables to nearby markets. These boxes are returned and used over and over until they are so badly broken that they are no longer serviceable.

Packing Vegetables for Market.—In packing vegetables for market there are three important considerations: (1) A satisfactory package for the product; (2) honest packing, which includes uniform product throughout the package and full measure; (3) careful placing of the product so that the specimens will remain in position until they reach the market and present an attractive appearance.

The package should be selected for the particular product, bearing in mind the protection of the product itself and also the demands of the market. In selecting a container for vegetables, to be shipped long distances attention should be given to its ability to withstand rough handling and to its desirability from the standpoint of stacking in the car, as well as to the possibility of quick cooling of the product.

Honest packing should be practiced because "honesty is the best policy." The packer, who puts up a dishonest pack fools no one but himself. The buyer is always on the lookout for dishonest packing and usually penalizes the produce and the producer, or packer. A few low grade goods in a package of high quality produce, governs to a large extent the price paid for the entire contents.

Transportation of Vegetables.—Market garden products are hauled direct to the market by wagon or motor truck, or shipped relatively short distances by local freight and express. The truck grower at a greater distance from the market, transports his produce by express, by through freight, usually in carload lots, or by boat. The transportation problem of the truck grower is much more complicated than that of the market gardener and the transportation expense is usually much greater with the truck grower. For most products, shipped long distances, refrigeration must be used and this adds to the cost of transporting. During very cold weather cars are often heated to prevent freezing the produce. Both refrigeration and car heating are items of expense almost unknown to the market gardener.

Transportation facilities have extended the area of production of perishable products from the limits of the wagon haul to the confines of the United States and even beyond. Fast freight and the refrigerator car now enable producers, located long distances from the market, to take advantage of climatic conditions to grow crops for the large Eastern markets, when these markets could not be supplied with local products. This has the effect of extending the season of consumption of many crops. Field-grown lettuce and celery are available practically throughout the year, and beans, peas, tomatoes, beets and many other crops are available from the field a large part of the year.

Transportation by water is cheaper than by rail and the cargoes are subjected to less injury from dust, dirt, heat and jolting. However, it requires a longer time to get produce to market by boat than by rail, hence the former is impracticable for very perishable products grown long distances from the market. A considerable portion of the products grown in southern Michigan is shipped by boat to Chicago, Milwaukee, and other lake ports; and produce from Norfolk, Virginia is shipped by boat to Washington, Baltimore, New York and Boston.

Selling Vegetables.—Vegetables are disposed of by producers by the following methods: (1) By retail to the consumer, through house to

house sales, city retail markets, roadside stands, or by parcel post and express; (2) by wholesale to retail dealers, wholesale dealers or jobbers; (3) by consigning to commission merchants who sell on commission and (4) by selling through a cooperative organization, which might use any or all of the last three methods.

Retail selling is not popular except with the small gardener since the time required to sell a load of produce by house to house calls, or even standing on a retail market requires too much time. Most growers feel that their time is of more value on the farm than in selling produce in small lots. This is probably true, for, on nearly all public markets a large percentage of the best gardeners sell in wholesale lots to retail merchants or other dealers or hucksters. One serious objection to retail selling on a public market is the absence of consumer buyers on days when the weather is very cold, very hot, or rainy. The produce must be marketed in all kinds of weather and it is natural for the producer to favor the buyers who are always on hand.

Wholesale selling is followed by a large percentage of market gardeners and by practically all truck growers. The latter are not located near enough to the markets to do a retail business. Market gardeners sell largely to stores and to hucksters, although they sell to hotels and restaurants, and also to wholesale dealers. Truck growers sell largely to wholesale dealers, jobbers or brokers. These may have representatives on the ground, who buy the produce outright at the shipping point, or the products may be sold by telegraph subject to inspection on arrival. Most growers prefer to sell to buyers at the shipping point rather than take chances on shipping produce subject to inspection on arrival.

Cooperative marketing by farmers has been employed to a limited extent for many years, but within the past 10 years hundreds of cooperative organizations have been formed for selling all kinds of agricultural products and for buying supplies. While cooperative associations can accomplish more for the farmer than he can accomplish for himself it should be remembered that there have been many failures and relatively few successes in this field. This fact should be a warning to go slowly and to study thoroughly the need of a cooperative organization, the reasons for success and failure, and the methods followed by successful organizations. Many failures have been due to lack of need of a cooperative association and lack of cooperative spirit, poor management and poor business methods.

Cooperative associations, to be successful, must be organized because of a real need and the members must have the proper attitude toward cooperation. In addition to these there must be a sufficient volume of business to make economical operation possible, there must be capable management, good business methods and loyalty to the association on the part of the members. An organization formed for the purpose of han-

dling a special crop is more likely to be successful than one organized to handle many crops. Each industry has its own problems to solve and its particular trade practices and connections with which to deal.

Some of the important services that a cooperative organization can render to the grower are: (1) Standardize the product; (2) improve the grading and packing; (3) develop old markets and find new ones; (4) effect savings through large scale handling, better distribution, etc.; (5) secure and disseminate crop and market information; (6) advertise the products of the members, and (7) buy needed supplies. Most of these things can be accomplished by an organization because funds are available to secure the services of experts along the various lines. This is impossible for most individual growers, since the volume of business is too small to bear the burden of all the services that a cooperative association can render.

CHAPTER XV

STORAGE OF VEGETABLES

Storage of perishable products is an economic necessity and the business of storage is an important element in modern marketing of vegetables. Storage stabilizes prices by carrying over goods from periods of high production to periods of low production, thus, preventing gluts on the one hand and bare markets on the other. Without storage the producer would be forced to put his crops on the market soon after harvest, regardless of the demand. This would cause a glut and market stagnation with consequent loss to the producer. While the consumer would benefit by lower prices during a glut he would more than make up for this later in the season when the demand became greater than the supply, resulting in very high prices. Without storage enormous losses would occur due to deterioration and decay, and this would increase costs to the consumer without benefitting the producer. One of the needs of the present time is more and better storage.

Requirements of Storage.—Successful storage of vegetables requires a good product to begin with, the proper moisture and temperature for the particular products to be stored, and fresh air. The product should not be over-ripe, in fact, many products keep best when harvested before they are fully matured. They should be practically free from disease and injury of all kinds. A diseased or injured product usually deteriorates rapidly in storage.

Specific rules regarding moisture and temperature that will apply to all products stored cannot be given. Some products as beets, carrots, parsnips and turnips keep best in a relatively cold, moist atmosphere, while others, as cabbage and onions require a cold dry atmosphere for best results. Sweet potatoes and pumpkins keep best in a relatively warm, dry atmosphere and deteriorate rapidly under moist, cool conditions. Control of moisture and temperature are secured in various types of storage structures by natural, or by artificial means.

Uniform moisture and temperature conditions are best for all products. Rapid fluctuations of humidity and temperature are inimical to good keeping, therefore the storage structure should be so constructed that rapid changes do not take place.

Storing in the Field.—Field storage, in trenches and pits, and by mounding on the surface of the ground, is still practiced to some extent.

Trenches are used for storing cabbage and celery and pits are employed for cabbage, turnips, beets, carrots, parsnips, potatoes, and sweet potatoes. All of the crops mentioned, except celery, are sometimes placed in piles on the ground and covered with hay, straw or other litter and then with soil. The covering of soil must be heavy enough to prevent severe freezing.

Field storage is unsatisfactory and is giving way to other methods. The main disadvantages of this type of storage are: (1) Temperature and moisture cannot be controlled; (2) difficulty of removing produce from trenches, pits, or mounds when the ground is frozen which may prevent marketing at the desired time; (3) injury to the product not removed when a pit, or mound is opened during cold or wet weather; (4) the large amount of labor required to store and remove the products by this method of storage.

During the time vegetable products are removed from field storage the weather and soil conditions are usually unfavorable for work of this kind. This is one of the factors that has caused a change in the method of storage on many farms.

The only advantage in field storage is that it is always available and any amount of space can be used as required. Many growers use field storage because they believe it is cheap, but when labor is taken into consideration it is an expensive method.

For short storage periods the mound above the surface of the ground is fairly satisfactory. A well-drained location should be selected so that no surface water runs about the base of the mound. The surface should be leveled and it is desirable to have two small trenches across the bed, at right angles to each other, to provide for ventilation at the bottom. Boards or troughs are often placed over the trenches and, at the intersection of the trenches, a small open box is set on end to form a flue up through the pile of vegetables. The earth floor is covered with 4 or 5 inches of hay, straw, or other litter and the product is placed on this in a conical pile around the flue. A covering of straw, hay or similar material is put over the pile and over this a layer of soil. The covering of soil should be only a few inches thick at first, but increased as the weather gets colder. The ends of the trenches and flue should be kept open for ventilation until it is necessary to close them to prevent freezing of the product. It is better to make several small mounds rather than to make one large mound, because when a mound is opened it is best to remove the entire contents.

Storing in Cellars.—The ordinary house cellar is used to a considerable extent for the storing of root crops for home use and also for market. This is likely to be one of the poorest places in which to store vegetables, if it contains a heater, as it is likely to be so warm and dry that the products will shrivel. However, by partitioning off a room, which can be

kept cool and fairly moist, the house cellar is satisfactory. The storage room should have an opening to the outside for ventilation.

Out-door cellars, made especially for storing root crops, usually give better results than the house cellar. With proper construction the temperature and moisture can be controlled to some extent. This type of storage structure may consist of a pit with a gable roof covered with sods or soil, or a more elaborate structure. Some of the more elaborate storage structures are built in a depression or ravine and covered with soil except at the ends. The structure built into a side hill, or in a ravine and covered with soil is preferable to the pit type since the soil on the sides and top prevents rapid changes in temperature. In any case the entire structure should be well-insulated and it is desirable to have the exposed end face the south. Strahan (147) gives the following rules for the construction of root cellars:

1. A root cellar should be located when possible in a side-hill facing the south or the southeast.

2. It should be completely covered with at least 2 feet of earth. When this is impossible by reason of the topography, the roof should be thoroughly insulated, special attention being given to the point where the roof joins the wall.

3. It should be provided with ventilation approximately as follows:

For cellars of from 1,000 to 5,000 cubic feet capacity at the rate of 60 to 80 square inches of flue area per 1,000 cubic feet capacity.

For larger cellars, from 5,000 cubic feet up, at the rate of from 45 to 60 square inches of flue area per 1,000 cubic feet capacity.

Intake ventilators should be provided of approximately the same area as the outtake flues. The inside ends of these should be located near or at the floor. The drain may be utilized as an intake ventilator.

4. Drainage should be provided by ordinary vitrified sewer pipe not smaller than 4 inches in diameter, and if intended for use as a ventilator not less than 6 inches. It must be thoroughly screened at both ends.

5. Doors should in all cases be double. Windows should be constructed in such a way as to make possible thorough insulation in cold weather by banking them with straw or other similar material. They should be well screened.

6. A dirt floor seems to be preferable to a concrete floor where good solid footing can be obtained. A concrete floor is preferable where it is necessary to exclude ground water due to local springs that cannot be diverted through drains.

Storage cellars are best suited to the storage of beets, carrots, parsnips, turnips and potatoes as these products keep best where the humidity is relatively high.

Storing in Above-ground Houses.—Common storage houses built entirely above the surface are extensively used in storing sweet potatoes, onions and cabbage, and also to some extent for other products. Where it is necessary to have a dry atmosphere in the storage house the cellar, or structure of the semi-cellar type is not satisfactory since it is difficult to control the moisture in structures of this kind.

The advantages of this type of storage over any of the others mentioned are: (1) Moisture can be controlled more readily; (2) products can be put in and taken out with less work and less discomfort; (3) grading and packing can be done to better advantage than from field storage or even in most types of cellars.

The character of construction of storage houses depends mainly on the type of product and the region in which it is to be stored. The colder the region the greater the amount of insulation needed. Sweet potato storage houses in the South differ considerably from the cabbage and onion houses in the North, yet the same general principles of insulation and ventilation are applied in the two regions.

Cold Storage.—During recent years many vegetables have been stored to some extent in cold storage warehouses where artificial refrigeration is used. The tendency is toward a greater use of this type of storage. The main advantage of cold storage over common storage is in the control of temperature and humidity, especially the former. In cold storage warehouses the temperature can be kept at the desired point regardless of the weather condition, provided the building has been properly constructed and equipped. This ready control of temperature is not possible in any other type of storage, consequently less loss is sustained under refrigeration than in common storage. For this reason cold storage is being used even for products which keep fairly well in common storage. At the present time cold storage is used for a large part of the celery, which is stored, and to some extent for lettuce, onions, potatoes, carrots, beets, cabbage, cauliflower and other vegetables. Practically all vegetables can be kept in cold storage for a short period, but very little is known regarding the best temperatures and the critical temperatures for the different products. For most vegetables kept in cold storage a temperature of 32 degrees F. or thereabouts is considered best, although for table potatoes this is too low.

Location of Storage Houses.—In the early development of storage the houses usually were built on the farm for use by the owner to store his surplus for home use, or for sale. While farm storage is still used to a considerable extent the tendency is toward commercial storage houses in the cities, or at some central railroad point in the producing region. The change from storage on the farm to use of large, commercial houses makes for more efficient storage. The main advantages of the large commercial houses over the small storage structures on the farms are: (1) Lower cost per cubic foot of storage space; (2) lower maintenance and management cost; (3) usually more efficient management, because large-scale storage permits of employment of efficient managers who devote their time to the business; (4) usually better equipment for handling produce at the storage house and therefore less labor required in doing the work; (5) better location with reference to transportation

facilities to markets. Produce stored in farm storage houses must be hauled to the market or to the shipping point during late fall and winter when the roads are likely to be bad and the weather cold. Sometimes it is impossible to get the farm-stored produce to market when there is the greatest demand and very often it is not safe to expose vegetables to the weather during winter. These factors often cause farmers to miss good markets. When the produce is stored in the consuming centers or on a good transportation line it can be placed on the market at any time, and for this reason central storage houses are more popular than farm storage houses.

Common storage houses, those having no artificial means of cooling, are usually located on the farms, or at some central point in the producing region. Cold storage houses are located mainly in the cities although a small percentage are located in small towns or villages in fruit and vegetable regions. The main advantage of locating storage houses in the cities is the convenience of marketing.

Cold storage space in the cities is usually controlled by dealers, hence the producer gets only an indirect benefit from such houses. This has led growers, in many sections, to build cold storage plants in the producing region. There is an advantage in having cold storage houses near the producing region especially for very perishable products such as celery and lettuce. The sooner perishable products are placed in storage after they are harvested the longer they will keep. In fact, if celery and lettuce are placed in storage after being in transit for several days, they will keep only a short time, due to the fact that the temperature in most parts of a refrigerator car is not low enough to prevent deterioration.

Effects of Storage on the Vegetable Industry.—Storage extends the period of consumption of many vegetables and this increases the demand. Without storage the consumer would be able to secure vegetables only during the time that they are available from the field in various sections of the country. With some crops this would cover a considerable portion of the year while with others it would cover a relatively short period. Sweet potatoes would be available for only 4 or 5 months while Irish potatoes and onions for 6 or 7 months. Without storage the acreage of many vegetables would have to be reduced, because it would be impossible to consume, during the harvesting period, all that is now grown. Storage therefore increases consumption by lengthening the period of availability of many standard vegetable products.

Storage increases the price the farmer receives for his products, even if they are stored by middlemen, because it helps to prevent market gluts. Cance, Machmer and Read (20) found that the average price paid to the farmer for onions for the 3 years 1913–1915 in Massachusetts was $1.14 per 100 pounds and the average wholesale price for onions out

of storage was about $2.20 per 100 pounds. The difference between the price paid the farmer and the wholesale price from storage covers cost of storage, cost of extra handling, loss due to shrinkage and disease, speculative risk and profit. The average monthly price paid for various products show the effects of storage on prices. Table XIV gives the average monthly price of sweet potatoes for 10 years, 1911 to 1920 as published in the "Monthly Crop Reporter" for December 1920 and also the average monthly price for the entire period. The average for the entire period was computed by the author from the figures given in the publication mentioned.

Table XIV.—The Estimated Average Price, Cents per Bushel, to Producers for Sweet Potatoes, Monthly for 10 Years; and the Average for the 10-year Period 1911–1920

	1920	1919	1918	1917	1916	1915	1914	1913	1912	1911	Average for 10-year period
Jan. 15	151.1	137.8	123.1	92.9	72.7	81.0	82.5	83.7	86.9	79.1	99.08
Feb. 15	163.6	149.2	129.8	100.0	76.4	85.0	86.1	87.0	93.5	81.6	105.2
Mar. 15.......	179.2	157.2	149.2	115.5	80.1	90.8	87.3	90.8	102.4	87.3	113.9
Apr. 15	193.9	176.2	158.1	126.0	81.0	100.8	91.9	94.3	117.4	95.0	123.4
May 15	199.7	174.4	158.2	132.6	78.9	98.1	92.7	93.2	118.6	103.6	125.0
June 15	205.2	162.7	134.0	135.8	83.9	97.6	92.5	90.8	111.4	93.8	120.7
July 15	200.7	159.7	142.1	124.4	87.5	93.1	94.5	89.4	113.0	104.1	120.8
Aug. 15	210.8	195.4	151.6	126.3	99.0	97.2	98.4	98.8	102.5	107.4	128.7
Sept. 15.......	190.0	174.6	164.3	120.3	88.1	80.0	90.1	89.8	88.9	97.9	118.4
Oct. 15.......	138.7	150.9	152.4	110.5	80.3	69.7	79.3	78.0	79.9	85.6	102.5
Nov. 15.......	116.5	135.1	137.4	105.6	80.3	62.9	72.3	73.4	73.7	76.2	93.3
Dec. 15	....	125.8	131.8	110.8	86.4	65.0	74.9	75.8	77.2	79.0	92.8

It will be noticed that there is great variation in prices during any one year and also great variation in the yearly averages. The lowest prices usually prevail during the harvest period and immediately thereafter and the highest prices obtain late in the storage season.

Variations in prices similar to those for sweet potatoes occur with cabbage, potatoes, onions and celery. With more storage there would be less variation in price from month to month but the yearly average might not differ very materially from what it is under present conditions.

CHAPTER XVI

CLASSIFICATION OF VEGETABLES

Before attempting to give an analysis of the methods of growing vegetables it seems desirable to classify the crops. Any method of classification systematizes to some extent the preparation and presentation of the material and eliminates unnecessary repetition of some of the principles of culture. While an alphabetical arrangement of crops is the best for reference, it does not contribute to an understanding of relationship or similarity of cultural requirements. There are four general methods of classification as follows: (1) A botanical classification; (2) a classification based on hardiness; (3) a classification based on parts used; (4) a classification based on essential methods of culture. A fifth method combining parts of the four mentioned may be used to advantage in grouping crops for discussion.

Botanical Classification.—A classification based entirely on botanical relationship is the most exact system, but in many cases this is of little value in giving principles of culture since crops within a family may vary widely in their requirements. Potatoes and eggplants belong to the same family but their requirements are very different. However, other crops in this family, as tomatoes, eggplants, and peppers, have similar requirements. Most of the vegetables belonging to the family Cucurbitaceae have similar cultural requirmenets as well as the same disease and insect pests. This is also true of plants in many other families.

The botanical system of classification is of value in showing relationship and is given to show the families represented, as well as the important vegetable crops belonging to each.

Gramineae, Grass Family
- Sweet corn, *Zea Mais* var. *rugosa*
- Pop corn, *Zea Mais*

Lilaceae, Lily Family
- Asparagus, *Asparagus officinalis*
- Onion, *Allium cepa*
- Garlic, *A. sativum*
- Leek, *A. Porrum*
- Chive, *A. Schoenoprasum*
- Shallot, *A. ascalonicum*

Chenopodiaceae, Goosefoot Family
- Spinach, *Spinacia oleracea*

Orach, *Atriplex hortensis*
Beet, *Beta vulgaris*
Chard, *B. vulgaris* var. *Cicla*

Aizoaceae
New Zealand spinach, *Tetragonia expansa*

Cruciferae, Mustard Family
Cabbage, *Brassica oleracea* var. *capitata*
Cauliflower, *B. oleracea* var. *botrytis*
Brussels sprouts, *B. oleracea* var. *gemmifera*
Kale, *B. oleracea* var. *acephala*
Kohl-rabi, *B. oleracea* var. *caulorapa*
Chinese cabbage, *B. pekinensis*
Mustard, *B. alba*, *B. nigra*, and others
Water Cress, *Roripa Nasturtium-aquaticum*
Cress, *Lepidium sativum*
Sea-Kale, *Crambe maritima*
Radish, *Raphanus sativus*
Turnip, *Brassica rapa*
Rutabaga, *B. Napobrassica*
Horse Radish, *Armoracia rusticana.*

Compositae, Sunflower Family
Lettuce, *Lactuca sativa*
Chicory, Witloff, *Cichorium Intybus*
Salsify, *Tragopogon porrifolius*
Spanish salsify, *Scolymus hispanicus*
Jerusalem Artichoke *Helianthus tuberosus*
Artichoke, *Cynara Scolymus*
Endive, *Cichorium endivia*
Cardoon, *Cynara Cardunculus*
Dandelion, *Taraxacum officinale*
Tansy, *Tanacetum vulgare*

Leguminoseae, Pulse or Pea Family
Bean, kidney bean, *Phaseolus vulgaris*
Lima bean, *Phaseolus lunatus* var. *macrocarpus*
Sieva bean, civet bean, P. *lunatus*
Tepary bean, P. *acutifolius*
Scarlet runner bean, P. *multiflorus*
Broad bean, *Vicia faba*
Cowpea, *Vigna sinensis*
Soybean, *Glycine hispida* or *Soja max*
Hyacinth bean, *Dolichos lablab*
Pea, *Pisum sativum*

Malvaceae, Mallow Family
Okra, *Hibiscus esculentus*
Roselle, *Hibiscus Sabdariffa*

Umbelliferae, Parsley Family
Celery, *Apium graveolens*
Parsley, *Petroselinum hortense*
Parsnip, *Pastinaca sativa*
Carrot, *Daucus carota*
Celeriac, *Apium graveolens* var. *rapaceum*

Chervil, *Anthriscus Cerefolium*
Polygonaceae, Buckwheat Family
Rhubarb, *Rheum rhaponticum*
Martyniaceae, Martynia Family
Martynia, *Martynia proboscidea*
Convolvulaceae, Morning Glory Family
Sweet potato, *Ipomoea Batatas*
Solonaceae, Nightshade Family
Potato, *Solanum tuberosum*
Tomato, *Lycopersicum esculentum* and L. *Pimpinellifolium*
Pepper, *Capsicum annuum*, and C. *frutescens*
Eggplant
Husk tomato, *Physolis spp.*
Cucurbitaceae, Gourd Family or Melon Family
Cucumber, *Cucumis sativus*
Muskmelon, *C. melo*
Gherkin, *C. Anguria*
Watermelon, *Citrullus vulgaris*
Squash, Pumpkin, Vegetable marrow, *Curcurbita Pepo, C. maxima and C moschata*
Chayote, *Sechium edule*

Classification Based on Hardiness.—Vegetables are often classified as "hardy" and "tender." Those classed as hardy will endure ordinary frosts without injury, while those classed as tender are killed when subjected to the same temperature. This implies that frost injury is the chief distinction between hardy and tender plants, but there are other distinctions. Some of the hardy plants will not thrive well under hot dry conditions so that in the North they should be planted early in the spring or late in the summer. Others will withstand frost and also thrive during hot weather of summer. Some tender vegetables do not thrive in cool weather even if no frost occurs. The terms "cool season" and "warm season" crops are used to suggest conditions under which the crops thrive best, rather than their susceptibility to frost injury.

Based on the temperature that the plants will withstand, some vegetable plants are hardy, some semi-hardy, others tender and still others very tender. The hardy ones may safely be planted before the date of the last killing frost in spring. The semi-hardy will not stand a hard frost but will grow in cool weather and are not injured by a light frost. The tender plants are injured or even killed by a light frost, but can withstand cool weather and a cold soil, while the very tender are injured by cool weather. This system of classification is of some value in connection with a discussion of time of planting. By grouping all hardy plants together general principles regarding time of planting can be given for the whole group. The semi-hardy, tender and very tender

plants may be grouped in the same way for discussion. This system is used in Chapter IX.

Classification Based on Parts Used as Food.—In this system of classification those crops grown for their leaves or stems are placed in one group. This group includes cabbage, kohl-rabi, collards, asparagus, rhubarb, all of the salad crops and all of the potherbs or greens. A second group includes those crops grown for their fruits, as melons, tomatoes, eggplants, beans, peas, etc., while a third group includes those grown for their flower parts as cauliflower and broccoli. Those crops grown for their underground portions; roots, tubers, bulbs and corms, as potato, sweet potato, beets, carrots, parsnips, radish, turnip, salsify, onions, garlic, dasheen and many others constitute a fourth group. In each of these groups the crops cover a great range of cultural requirements so that grouping them in this way is not of much value.

Classification Based on Methods of Culture.—A system of classification based on essential methods of culture is very convenient. In this system all those crops which have similar cultural requirements are grouped together for discussion. This makes it possible to give the general cultural practices for the group without the necessity of repetition in the discussion of individual crops. This system combines some parts of the other three methods. In some of the groups, as cucurbits, beans and peas, bulb crops, and cole crops, all crops considered in each belong to the same family. In other groups as perennial crops, potherbs and greens, salad crops, root crops and the potato crops more than one family is represented in each group. In the perennial crops group of six vegetables five families are represented.

In teaching principles of vegetable gardening this system of classification has been found more satisfactory than any other and is followed in a general way in this book. In some of the groupings the crops within a group do not have much in common, but they are placed together for convenience. The vegetables discussed are placed in eleven groups and the discussion for each group constitutes a chapter. The grouping is as follows:

Group 1. Perennial Crops.
Asparagus, Rhubarb, Artichoke, Jerusalem Artichoke, Sea-kale, Udo.

Group 2. Potherbs or Greens.
Spinach, New Zealand Spinach, Orach, Kale, Chard, Mustard, Collards, Dandelion.

Group 3. Salad Crops.
Celery, Lettuce, Endive, Chicory, Cress, Corn Salad, Parsley, Salad Chervil.

Group 4. Cole Crops.
Cabbage, Cauliflower, Broccoli, Brussels sprouts, Kohl-rabi, Chinese Cabbage.

Group 5. Root Crops.
Beet, Carrot, Parsnip, Turnip, Rutabaga, Salsify, Turnip-rooted Chervil, Skirret, Radish, Horse-radish, Schorzonera or Black Salsify, Scolymus or Spanish Salsify.

Group 6. Bulb Crops.
Onion, Leek, Garlic, Shallot, Ciboul, (Ciboule) or Welsh onion, Chive or Cive.

Group 7. The Potato Crops.
Potato or Irish Potato, Sweet Potato

Group 8. Peas and Beans
Pea, Bean, Broad Bean, Common or Garden Bean, Multiflora Bean, Sieva and Lima Beans, Tepary Bean, Soybean, Cowpea.

Group 9. Solanaceous Fruits.
Tomato, Eggplant, Pepper, Husk tomato or Physalis.

Group 10. The Curcurbits.
Cucumber, Gherkin, Muskmelon, Watermelon, Citron Melon, Pumpkin, Squash.

Group 11. Sweet Corn, Okra, Martynia.

CHAPTER XVII

PERENNIAL CROPS

Asparagus	Jerusalem Artichoke (Girasole)
Rhubarb	Sea-Kale
Artichoke	Udo

Perennial crops occupy the land for a period of years and therefore should be located where they will not interfere with the usual tillage operations. It is advisable to grow perennial crops in an area to themselves. In the home garden these crops should be planted on one side, or one end so that the remainder of the garden can be treated as a unit in plowing and harrowing. For the same reason on commercial vegetable farms the perennial crops should be grouped together in one field, or in one portion of a field. After perennial crops have been planted manures and fertilizers are applied mostly as surface applications. Except for the points mentioned the perennial crops have little in common as far as cultural practices are concerned.

ASPARAGUS

Asparagus is one of the most delicate, wholesome, and appetizing products of the garden. Its early appearance in the spring, together with the fact that an asparagus bed when once established will produce for many years, makes it of special importance in the home garden as well as in the market garden and on the truck farm. As a canned product asparagus is one of the best because it retains its flavor better than most other vegetables.

The production of asparagus for market and for canning is an important industry. According to the census report of 1920 the commercial crop of asparagus grown in the United States in 1919 was valued at $5,102,135. The total number of acres grown for market was 30,244 of which California had over half, or 17,444 and was followed by New Jersey with 3,603, Illinois 2,128, Massachusetts 1,157, South Carolina 1,145, Pennsylvania 931 and New York 694 acres.

History and Taxonomy.—Asparagus is indigenous to Europe and Asia where it has been in cultivation for over 2,000 years. It was prized as a food by the Greeks and Romans and all parts of the plant were valued for their medicinal properties. Asparagus has been grown in the gardens of America ever since the earliest settlements were established.

Asparagus, a genus of the lily family, has at least 150 species native of Europe, Asia and Africa. Some of these are herbaceous and some woody, and both erect and climbing forms are common. In addition to the edible asparagus, the genus contains the so-called "smilax" used by florists and the ornamental plants known as "asparagus ferns." The species of this genus are devoid of ordinary green leaves, the green branches functioning as leaves. The small scales or spines on the stems are the true leaves.

The garden asparagus, *A. officinalis*. Linn. var. *Atilis* Linn. is a perennial, diœcious herb 4 to 10 feet tall. The male flowers are yellowish green and conspicuous, while the female flowers (on separate plants) are less conspicuous. The fruit is a three-celled berry which becomes red as it matures. The seeds are large (1/8 inch or less in diameter) rounded at the back, but more or less flattened on one side, black in color.

Soil Preference.—Asparagus can be grown on nearly all kinds of soils, but a deep, loose soil is preferred. Sandy and sandy loam soils are used to a large extent in many asparagus growing sections, although some of the muck lands of California are considered almost ideal. From the standpoint of market asparagus, where earliness is of great importance, sandy and sandy loam soils have a decided advantage. The soil should be well drained since the asparagus plant will not endure being submerged for any great length of time.

The preparation of the soil is an important part of asparagus cultivation. If the soil is not naturally deep it should be deeply plowed and subsoiled so as to give a bed at least 10 to 12 inches in depth. The soil should be as thoroughly freed of noxious weeds as possible since it is very expensive to control weeds in an asparagus bed. The soil should be thoroughly harrowed and pulverized before planting the asparagus roots.

Propagation.—Asparagus plants are grown from seeds sown in a well-prepared seed bed. The soil for the seed bed should be rich and the seed should be planted as soon in spring as the ground can be prepared so as to have benefit of a full growing season. The seed is usually sown in drills 15 to 18 inches apart for hand cultivation, or 30 to 36 inches for horse tillage, and it is covered about an inch deep. Germination is very slow, but it may be hastened by soaking the seed in warm water a day before planting. After the plants are established they should be thinned to stand 3 or 4 inches apart in the row. Frequent cultivation throughout the growing season is desirable, especially when weeds are troublesome.

One year old roots are preferred to older ones for transplanting. The plants may be dug at the end of the season and stored for use the next spring, or they may be left in the seed bed until time for planting. Since

the seedlings vary considerably it is important to select only the strong, healthy plants. The weak ones should be discarded.

Sowing asparagus seed in the permanent bed has been recommended and it has been claimed that one season's time is gained. Under ideal conditions there may be some advantage in this method since transplanting checks the growth of a plant, but it is not to be recommended for the average grower. There is less chance for selection of strong healthy roots and the plants would not be as evenly spaced under this method as under transplanting. It is important to have the asparagus roots planted 10 to 12 or more inches deep and if the seed were planted in a trench, there would be danger of soil washing into it and covering the seed to such a depth that many would not germinate. This would result in an uneven stand of plants.

Another method of starting plants is to sow the seeds in the greenhouse or hotbed two to three months before the outdoor planting season. The best seedlings are transplanted into small pots and are shifted into larger pots later. By this method plants make a good start before being set in the field and large, strong plants are secured the first season. The amount of marketable asparagus available during the early life of the bed would be increased by this method.

Manures and Fertilizers.—Asparagus is a fairly heavy feeder and, since it is often grown on poor soils, it should be liberally fertilized. Many growers in the East apply one ton or more of high-grade fertilizer to the acre, using a mixture containing 4 to 6 per cent ammonia, 6 to 8 per cent phosphoric acid and 4 to 8 per cent potash. Some growers use manure in addition to the chemicals and others depend almost entirely on animal manures. It is thought by many that manure is essential to asparagus, especially on sandy soils, but experimental results secured in Massachusetts by Brooks and Morse (17) do not justify this belief. They have shown that on sandy soils moderate applications of chemical fertilizers give as good yields as manure alone, or as a combination of manure and chemicals. The yield of 4 crops of asparagus on $\frac{1}{20}$-acre plat, given an application of 10 tons of manure per acre each year, was 1,186 pounds. On an adjoining plat, fertilized with 466 pounds of nitrate of soda, 300 pounds of 14 per cent acid phosphate and 346 pounds of muriate of potash, the yield was 1,265 pounds of asparagus. Four plats which received an application of the same amount of nitrate of soda and acid phosphate and 260 pounds of muriate of potash to the acre produced an average yield per plat of 1,189 pounds. Manure at the rate of 10 tons plus 466 pounds of nitrate of soda, 300 pounds of acid phosphate and 260 pounds muriate of potash to the acre produced a yield of 1,142 pounds of asparagus. As a result of the experimental work on fertilizers Brooks (17) gives the following conclusions:

In commercial asparagus growing as usually carried on in this State it is a common practice to apply what appears to be excessive quantities of fertilizers.

The medium amounts of the several plant-food constituents applied in these experiments appear to have furnished the different leading elements of plant-food in as large quantities as could be utilized by the crop.

These medium amounts are at the following rates per acre:

Nitrate of soda	460 pounds
Acid phosphate	300 pounds
Muriate of potash	260 pounds

Nitrate of soda at the rate of 400 pounds per acre in connection with manure at the rate of 10 tons per acre increased the crop, and appears to be the maximum amount which proved beneficial.

Among the different materials employed to furnish potash, the muriate, everything considered, proved most satisfactory.

The application of either acid phosphate or muriate of potash with manure at the rate of 10 tons per acre appears not to have increased the crop.

The immediate or even the cumulative effect of yearly applications of manure in increasing the humus content of the soil does not appear to have been beneficial; in other words, chemical fertilizers upon this sandy soil give as good results as manure.

The lack of benefit which can be attributed to humus furnished by the manure may be explained in part by the practice of our commercial asparagus growers in allowing the tops grown subsequent to the cutting season to remain on the ground to be worked into the soil the following spring.

The conclusion appears to be justified through observations upon the root habit of the asparagus, that yearly replacement of roots used when relatively young for the storage of reserve material by younger roots is also an important factor in accounting for the lack of beneficial effects resulting from humus furnished by manure. The roots thus replaced decay, thus adding to the organic matter of the soil.

The season of application of nitrate of soda does not appear to affect the relative yield of commerical asparagus in successive 10-day periods throughout the season; in other words, the cut of commercial asparagus during the early part of the season is not increased by either small or large applications of nitrate as early as the soil can be worked.

The season of application of nitrate of soda does appear to influence the susceptibility of asparagus to rust, which I am convinced is reduced by the application of at least a portion of the nitrate of soda at the close of the cutting season.

Fertilizer experiments at the Maryland Station on a medium loam soil gave results similar to those quoted above. However, 20 tons of manure produced the highest yields at the Maryland Station (See *Bull.* 151), but the cost of manure was so great that there was no profit. Kainit gave the highest net gains, but not the highest yield. Dissolved rock at the rate of 400 pounds, kainit 400 pounds and nitrate of soda 200 pounds to the acre produced the second highest yield and was considered the best fertilizer under average conditions. Muriate of potash

and kainit gave better results than sulphate of potash. Fertilizer applications made in the spring gave better results than when they were made at the end of the cutting season.

Salt.—Years ago salt was considered essential to success in growing asparagus, but at the present time it is not used by many commercial growers. It certainly is not essential since good asparagus is produced without its use. Some writers have advocated the use of salt to keep down weeds, but it is questionable if enough could be used to destroy weeds without injurying the asparagus. However, Walker (170) reports results of an experiment in Arkansas which indicate that salt was beneficial. The salt was applied at the rate of 1,000 pounds to the acre on a plat 1/14 acre in size. The yield on the salt plat was about 13.5 per cent greater than on the check plat. This increase is not significant since there was only one plat and the results are for just one year, the third year of life of the bed. Walker, however, believed that the salt was beneficial as the following statements show:

> These results show a decided difference in favor of the salted area amounting to 13.5 per cent, or a difference of 103.32 pounds per acre for the planting in its third year.
>
> The difference was not confined to the spring growth. There was an increased vigor manifest throughout the summer, and furthermore a noticeably increased glaucous appearance in the salted plants.
>
> In the quantity used, salt proved efficient in preventing the growth of weeds. Without any hoeing whatever but very few weeds appeared and those late in the season. While in the unsalted part they appeared abundantly as the season advanced until the end of the cutting when the entire planting was worked over.
>
> While the beneficial action of salt was attributed in part to its effects in preventing weeds, in this sandy soil there appeared to be an effect and beneficial action beyond what weeds would wholly account for.

At the Maryland Station 2,000 pounds of salt seemed to have no effect on keeping down weeds.

Some authorities believe that chlorine in muriate of potash, in some way, has a beneficial effect on the growth of asparagus and that this accounts for the higher yields from muriate than from sulphate of potash. There is no experimental evidence to justify this belief, but if it is true there is reason to believe that salt would be beneficial in the absence of muriate of potash or kainit. The consensus of opinion is that salt is of very little importance in asparagus growing, especially when muriate of potash is used as a fertilizer.

Planting Asparagus Roots.—One year-old roots are preferred to older ones, but these should be of good size. The small roots should be discarded, for if planted they make a slow growth. At the Pennsylvania Experiment Station an experiment was conducted for 6 years to determine the effect of size of roots on yields and returns. The roots were graded into three sizes and designated as Grade 1, Grade 2 and Grade 3.

The 6 years' results of this experiment, as reported in *Bull.* 147: 33–34, is given in Table XV.

TABLE XV.—EFFECTS OF SIZE OF ASPARAGUS ROOTS ON VALUE OF THE CROP FOR 6 YEARS AT THE PENNSYLVANIA EXPERIMENT STATION

Year	Grade 1	Grade 2	Grade 3
1910	$ 106.42	$ 114.14	$ 58.66
1911	290.88	265.92	118.16
1912	582.72	550.56	444.96
1913	693.12	648.48	538.56
1914	816.72	803.04	694.32
1915	744.28	742.28	656.64
Total	$3,234.14	$3,124.42	$2,511.30

A glance at the figures in Table XV will show that it would have been better to have discarded the smallest roots. The difference between the value of asparagus produced each year from the large and the small roots would have paid for the best and largest roots.

In most sections of the country asparagus roots should be planted in the spring as early as conditions will allow, but in the South they are often planted in the autumn.

Asparagus roots should be planted at least 8 to 10 inches deep since the crown develops a little higher each year and unless deep planting is practiced it is only a few years until the crown would be injured by the harrow and cultivator. On light soils planting 12 to 15 inches deep is not uncommon. In planting a commercial bed deep furrows are opened by running a turnplow two or four times where each row is to be located. The rows should be 4 to 5 feet apart for green asparagus and 6 to 8 feet apart for white shoots, since in producing the latter the soil must be mounded over the row. After the furrow is opened the roots are set 18 to 30 inches apart in the row, the greater distance being required for large growing varieties on rich soil. The roots are placed in the bottom of the furrow or trench and at first covered to the depth of 2 or 3 inches. Soil is added as the plants grow until by the end of the season, the furrow is filled. The filling in of the furrow is done as the land is cultivated. The crowns should not be covered to the extreme depth at first as the young shoots may be smothered before they reach the surface.

Cultivation and Care.—During the first season a crop of snap beans, early cabbage, lettuce or other hoe crop may be planted between the rows of asparagus. Tall-growing, or long-season crops should not be grown with asparagus on account of shading and competition for moisture and nutrients. The cultivation required by the asparagus will be sufficient

for the companion crop also and the return from such a crop should go a long way toward paying the cost of growing both. Cultivation and hand hoeing should be given as often as necessary to keep down weeds and to conserve soil moisture.

FIG. 8.—A disk asparagus hiller used for making ridge over the row in the production of white shoots. (*Courtesy of U. S. Department of Agriculture*).

After the first season the asparagus bed should be thoroughly disked and harrowed each spring. If the fertilizer is applied in the spring it should be done before the land is harrowed as the harrowing mixes it with the soil and gets it well distributed. Cultivation and hoeing is

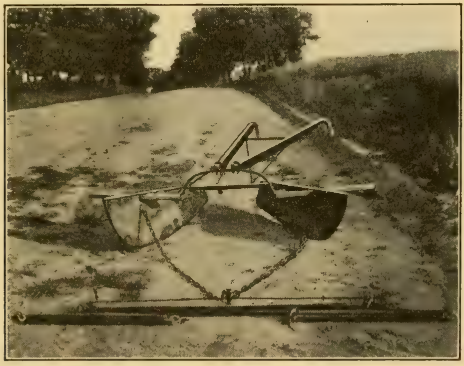

FIG. 9.—A type of asparagus hiller used in some regions for making a ridge over the row in the production of white shoots. (*Courtesy of U. S. Department of Agriculture*).

necessary to keep down weeds after the bed is established as well as during the first season. In all tillage operations care must be exercised to prevent injury to the crowns of the plants. Where blanched asparagus is desired it is necessary to mound the soil over the rows of asparagus in order to bleach the young spears. On large plantations this is done by

means of a plow, a disk harrow or with an asparagus hiller similar to those shown in Figs. 8 and 9. The hilling is started in the spring, just as growth begins and continues through the cutting season as needed to keep up the mounds.

After the cutting season the mounds are leveled and flat culture is given during the remainder of the season. If any of the fertilizer is applied at the end of the cutting season it should be applied between the rows and mixed with the soil by cultivating. It should be borne in mind that the treatment given the asparagus bed during the growing season determines, to a very large extent, the quality and quantity of the crop the following year. The plant food used in the production of shoots in the spring and early summer is manufactured in the foliage and stored in the roots during the previous season's growth. For this reason a strong, healthy growth of foliage is essential to a good yield of shoots.

Removing the Tops.—Some authorities advise cutting and burning the asparagus tops as soon as the berries turn red, and this is the practice in many regions. It is argued that if the berries are allowed to ripen and fall off the seeds will germinate and the young plants become troublesome. If the tops are removed while they are still green the roots are deprived of a large amount of reserve food material. The asparagus tops are a great protection to the roots in regions where low temperatures occur, since they hold the snows and thus prevent deep freezing and rapid changes in the soil temperature. For this reason, it is desirable, under most conditions in the North to leave the tops stand until spring and then disk them into the soil.

Morse (98) has shown that early removal of asparagus tops decreases the amount of reserve food material stored in the roots and also that most of the material used in growth of shoots is stored in the roots during the previous season. Samples of tops were taken for analysis in August, after blossoming but before berries were formed, and in October, when the stalks had turned yellow. To determine how fast translocation took place the branches were removed and analyzed by themselves. Table XVI gives the results of the analysis as given by Morse (Mass. *Bull.* 171).

A study of Table XVI shows that both the sugar and protein disappear with ripening, and appear to be the only groups of constituents subjected to translocation. The translocation of sugars as they are formed is indicated by the higher percentages in the stalks than in the branches, both in midsummer and in autumn.

Asparagus tops from six plants were gathered November 4, 1914, when they were golden yellow in color and bare of needles. Dry matter, sugar and protein were determined with the following results:

Dry matter	49.45
Sugar	4.08
Protein	4.70

Table XVI.—Analysis of Asparagus Tops

	Summer tops		Fall tops	
	Stems	Branches	Stems	Branches
Dry matter	23.76	28.43	24.18	32.15
Ash in dry matter	7.39	7.31	9.36	8.51
Protein	7.94	17.31	4.47	11.00
Fiber	44.83	29.76	45.11	32.02
Fat	1.38	4.89	1.35	5.23
Nitrogen-free extract	38.46	40.73	39.71	43.24
Total sugar	14.28	8.68	9.34	7.09
Pentosans	15.90	14.15	15.86	14.41
Lignin	8.28	17.90	14.51	21.74
Reducing sugar	12.50	2.99	8.76	3.99
Protein nitrogen	1.03	2.42	0.74	1.56
Amino nitrogen	0.24	0.35	.....	0.20

On the transferrence of sugar and protein from the tops to the roots Morse (98) says:

It is probable that neither sugar nor protein is completely transferred to the root, because until killed by frost the living cells must still contain active protoplasm, and its supply of food.

Analyses of asparagus roots show that most of the reserve material stored in them in the fall is sugars. Table XVII adapted from Massachusetts *Bull.* 171 gives the composition of roots in November 1910 and June 1911:

Table XVII.—Composition of Asparagus Roots

	November, 1910	June, 1911
Dry matter	21.10	18.62
Ash in dry matter	6.89	8.93
Protein	12.44	12.75
Fiber	19.77	23.66
Fat	1.77	1.63
Sugar in dry matter	31.52	23.20
Pentosans	10.96	11.66
Lignin, etc	16.65	18.17

On the results of these analyses Morse says:

> There was a pronounced exhaustion of sugars in the spring growth, but none of the other constituents, instead, the other constituents were increased in proportion to the loss of sugars. Nitrogen, which would be also indispensable to new growth, was not consumed at the rate of sugar but was transferred to the growing stalks at a rate which left its proportion in the parent crown almost unchanged.

To determine the effects of various fertilizer treatments on the composition of asparagus plants, analyses were made of roots, shoots and tops of plants grown under different treatments. On the results of these treatments on the composition of the roots Morse (98) gives the following summary:

> Withholding one of the constituents of a complete fertilizer from the annual top dressing was accompanied by a smaller average weight of roots in the samples taken from the plat thus treated. Withholding nitrate of soda lessened the percentage of nitrate and of soda in the roots; withholding acid phosphate produced no apparent change in the constituents of the roots.
>
> An increase of nitrate of soda from the minimum to the medium amount in the top dressing caused an increase in the percentage of nitrogen in the dry matter of the roots.
>
> An increase in the amount of muriate of potash produced some increase in the percentage of potash in the roots.
>
> The fertilizing constituents which were stored in the roots over winter appeared to be nearly, if not quite, sufficient for the full development of the succeeding spring crop. There was evidence of a small intake of nitrogen during the cropping season, and a pronounced absorption of lime and sulphuric acid.

Duration of a Plantation.—The length of time an asparagus bed will produce profitable yields depends upon the treatment it receives and to some extent upon the depth of planting. The deeper the roots are planted the longer it will take for the crowns to come near enough to the surface to be injured by harrowing. A well-established bed, which receives good cultivation to keep down weeds, and good fertilizing each year should produce profitable crops for 15 years. In practice, however, it is usually found desirable to renew the planting about every 10 years. When an old bed produces nothing but small, spindling shoots it should be plowed up. Of course, a new bed should have been started in another location some years previous to the time the old bed is destroyed, in order to have a supply of asparagus every year.

Varieties.—True varieties of asparagus are few and the characteristics of these are not clearly marked since there is a constant mixing of blood lines due to crossing in the field. Reading Giant, Argenteuil and Palmetto are three good varieties resistant to the asparagus rust. A type of asparagus developed by the U. S. Department of Agriculture and known as "Washington" is more rust resistant than any other asparagus on the market. A named strain called Mary Washington is

the best of the Washington strains in quality and commercial value. It is quite resistant to rust, produces large shoots which do not branch as quickly as most varieties of asparagus. The buds remain closed longer than in any other variety or strain.

Asparagus Rust.—The asparagus rust (*Puccinia asparagi*) is the only serious disease of asparagus in the United States. The disease appears on the plant as small reddish-yellow spots on the main stem and on the branches. As the disease develops, the spots enlarge into patches until the whole plant has a reddish-brown or orange color, which becomes darker later in the season.

FIG. 10.—A field of asparagus showing the effects of rust. The new field of the Reading Giant Variety on the left was grown as a breeding field for rust-resistance work. (*Courtesy of U. S. Department of Agriculture*).

The damage caused by the asparagus rust is not seen directly in the marketed product, but reduces the yield by weakening the plants during the summer after the cutting season is over and often killing them as shown in Fig. 10. No practicable control measure has been developed for this disease except the use of rust-resistant varieties. Spraying with Bordeaux mixture has been thoroughly tested by several experiment stations but growers have not taken up the practice. The use of rust-resistant varieties is the only solution of this problem.

Asparagus Beetles.—Asparagus is attacked by two species of beetles, the common asparagus beetle (*Crioceris asparagi L.*) and the 12-spotted asparagus beetle (*Crioceris duodecimpunctata L.*). The adult of the common asparagus beetle is slender, blue-black with red thorax and lemon-yellow and dark blue wing covers. The length of the body is about 1/4 inch. The full-grown larva is dark gray, with shiny black head and legs. The twelve-spotted asparagus beetle can be distinguished from the common species by its broader back and orange-red color. Each wing

cover is marked with six black dots. The larva of this species is orange in color and about three-tenths of an inch long.

Injury by the common asparagus beetle is due to the work of both the adults and larvae to the tender shoots, and to the plants later in the season. The larvae feed upon the tender portion of the tops, but the beetles gnaw the epidermis or rind of the stems as well as the tender portions. This injury to the asparagus tops results in weakening of the roots. The chief damage inflicted by the twelve-spotted asparagus beetle is by the adult upon the young shoots in the spring. Later both the adults and larvae feed upon the berries.

Among the control measures recommended are: (1) Keep the asparagus cut in the spring and starve the beetles; (2) allow chickens and ducks to run in the patch; (3) leave a few plants for the beetles to feed upon and spray with an arsenical; (4) dust the plants with air-slaked lime while the dew is on to destroy the larvae of the common asparagus beetle, (5) spray or dust plants with arsenicals after the cutting season to kill both adults and larvae of the common species; (6) clean up rubbish in the fall and (7) brush or beat off the larvae of the common asparagus beetle with a stick during a bright warm day. None of the methods mentioned will destroy the larvae of the twelve-spotted beetle, but this stage is seldom very injurious. Spraying with arsenicals to catch the adult in the spring is the most effective method of control.

Harvesting.—During the first and second years of an asparagus bed no shoots should be cut, and even during the third year the cutting season should be short. After a bed has become well established the cutting season may be of 8 weeks' duration.

Asparagus is usually harvested every day during the main portion of the cutting season, but if the weather is cold every other day, or even every third day may be often enough. On the other hand, in very hot weather, when the growth is very rapid, it is necessary to go over the bed twice a day, especially where blanched shoots are desired. The cutting is done with a knife made especially for this purpose. In cutting one takes hold of the shoot with one hand and with the other hand inserts the knife to the desired depth, an inch or two below the surface of the soil for green asparagus, and severs the shoot with a downward stroke. Care must be exercised to avoid injuring the crown and the other shoots, hence the knife should be inserted almost straight down beside the shoot, and then tilted slightly to cut off the stalk. One thrust with the knife should be sufficient.

The workman usually cuts two rows at once. The shoots are placed in a basket as cut, or are held in one hand until it is full when they are laid on one of the two rows being cut. The small piles are then gathered by other workers. Whatever method is used the shoots should be gathered before they become wilted.

If white asparagus is desired it is necessary to cut the shoots soon after they force their way through the surface of the soil. They turn green on exposure to the light. White shoots are cut several inches below the surface of the mound of soil, but they should be severed an inch or two above the crowns to avoid injury to the crown or roots.

Since asparagus loses its quality quickly after it is harvested it should be prepared and put on the market as soon as possible. For the very highest quality, asparagus should be cooked within a few hours after being cut, but this is impossible except where it is produced at home. However, the local gardener has a decided advantage over the grower who lives a long distance from the market.

Washing Asparagus for Market.—The asparagus shoots are usually taken to the packing shed where they are washed, bunched and packed. This preparation may be done in almost any kind of a building. The necessary equipment and supplies consist of stationary benches or tables, tubs or tanks, brushes and wire bottom trays for washing, machines for bunching, knives, tape or raffia, shallow pans, crates or boxes, labels, nails and a supply of water. The shoots are usually washed before bunching and this can be done easily by dousing the tray of shoots a few times. Green asparagus does not always need washing, but the butt ends usually require some rinsing to give the bunch a clean appearance. This is sometimes done after the shoots have been bunched. Some growers prefer to scrub the outside of the bunch of shoots after they have been bunched and tied, and for this a stiff brush is used.

Grading.—Asparagus stalks should be separated into grades based on size, length and general appearance. Three grades are made. The large, straight stalks of good length and free from injury constitute the best grade and may be called "fancy." The next grade consists of medium size, straight stalks of good length and the third grade consists largely of the small stalks, but may include any marketable stalks which do not belong in either of the other two.

The U. S. Bureau of Markets has suggested two grades for asparagus: U. S. No. 1 and U. S. No. 2 with specifications as follows:

U. S. No. 1 shall consist of clean, fresh stalks of asparagus which are not wilted or crooked; which do not show broken or spreading tips and which are free from damage caused by disease, insects or mechanical or other means.

In order to allow for variations incident to proper grading and handling, not more than 10 per cent, by count, of any lot may be below the requirements of this grade but not to exceed one-half of this tolerance shall be allowed for any one defect.

U. S. No. 2 shall consist of stalks which do not meet the requirements of the foregoing grade.

As used in these grades:

Free from Damage means that the asparagus shall not be injured to an extent readily apparent upon examination.

In addition to the statement of grade, any lot of asparagus may be classified as Small, Medium or Large, if 80 per cent, by count, of the stalks in any lot conform to the following requirements for such sizes:

Small, $\frac{3}{8}$ to $\frac{9}{16}$ inch. Medium $\frac{9}{16}$ to $\frac{3}{4}$ inch. Large over $\frac{3}{4}$ inch.

The above measurements refer to the diameter of the stalks measuring at a point not more than 8 inches from the tip.

Bunching.—After separating the shoots into the different grades they are placed in a bunching machine with the heads all one way, only one grade being put into a bunch. When the bunching apparatus is full the clamps are closed and the asparagus is tied near each end with tape or raffia. The butts are cut off evenly with a sharp knife and the bunches packed immediately, or else placed in a cool place not exposed to currents of air. The size of bunches range from one pound to three pounds depending upon the market. For local retail trade small bunches are preferred.

Packing.—Several types of packages are used for asparagus, the most common one being a box having solid ends or heads, and made especially for this product. These boxes are made to hold one, two or three dozen bunches set on end. The tops of these boxes are 2 to 3 inches narrower than the bottoms thus preventing the bunches from shifting. Small boxes are used in some sections, especially for a fancy product. A common type of box is made with heads 15 inches wide at the top and 17 inches at the bottom, and with the side, top and bottom slats 26 inches long. The 32-quart strawberry crate is used in some sections for shipping asparagus short distances. Twenty-four bunches, weighing $2\frac{1}{2}$ to 3 pounds, are packed in each crate, the bunches being placed on their sides. This type of package does not show off the asparagus to as good advantage as the asparagus box or crate. The California crate is one of the best. It is ($9\frac{1}{2}$ by 11) by $10\frac{3}{8}$ by $17\frac{13}{16}$ inches inside measurements and holds one dozen bunches of asparagus. The South Carolina crate is about the same size and shape, while the New Jersey crate is larger ($14\frac{1}{2}$ by 19) by $11\frac{3}{4}$ by 23 inches inside and holds 2 dozen bunches. The Illinois growers use boxes having 20 to 24 compartments similar to the divisions of an egg crate. Each compartment contains one bunch of asparagus. The boxes are 6 by 8 by $20\frac{3}{4}$, 6 by 8 by $21\frac{3}{4}$, 4 by 8 by $20\frac{3}{4}$ and 4 by 7 by $20\frac{3}{4}$ inches inside. The boxes and crates are often lined with paper to prevent excessive drying of the product. A thin layer of damp moss is sometimes used in the bottom of asparagus crates and the butt ends placed on this to keep the cut surface from drying.

RHUBARB

Rhubarb is grown for its large, thick, leafstalks or petioles, which are used for sauces and pies. It is used in the diet in the place of fruit. Since rhubarb is available early in the season it is a popular article of food.

In the home garden the rhubarb bed should be located on one side or one end along with the other perennials so that it will not interfere with preparation of the remainder of the area. In commercial plantings it should be planted in a block by itself or with other perennials for convenience in tillage operations.

History and Taxonomy.—Rhubarb is a native of Asia (Siberia) and has been grown in the United States since about 1800. It is a member of the buckwheat family, Polygonaceae, and the genus Rheum, which contains about 25 species. *Rheum rhaponticum* or common rhubarb has large roots branching from the crown. The first leaves grow from the crown at or near the surface of the ground, but the flower stem which appears later also contains leaves. The stem leaves are smaller in size than those coming direct from the crown. The stem grows 4 to 6 feet tall, is hollow, and has conspicuous nodes. The flowers are numerous in successive panicles, very small, greenish-white, on slendor pedicels.

Soil Preferences.—Rhubarb can be grown on almost any type of soil, but a deep rich sandy loam is considered best. Where rhubarb is grown on a light soil it should be heavily manured or a cover crop turned under to supply humus.

The soil should be plowed 8 to 10 inches deep and thoroughly pulverized by whatever means are necessary. This may include disking, harrowing, dragging or rolling.

Manures and Fertilizers.—Unless the soil is already rich it should be heavily manured, or fertilized since rhubarb is a gross feeder. Where manure is available a yearly application of 20 tons to the acre may be used to good advantage. This is usually applied in the fall or during the winter. If manure is not available an application of 1,500 to 2,000 pounds of a high-grade fertilizer to the acre should be applied each year. On sandy loam soils a mixture containing 5 per cent ammonia, 8 per cent phosphoric acid and 6 to 8 per cent potash should give good results. On a fairly rich, loam soil both the nitrogen and potash may be reduced. Since rhubarb starts growth in the spring from the reserve food stored in the roots, during the preceding season, it is essential that sufficient nutrients be available to make a good growth of foliage after the harvest season.

Propagation.—Rhubarb is easily grown from seed, but as only a small percentage of the plants produced in this way are true to type the more common method of propagation is by division of the roots. Where seed is used it should be planted in rich, well-prepared soil early in the spring. The rows may be spaced 15 to 18 inches apart for hand cultivation or 30 to 36 inches apart for horse cultivation. It requires a year's more time from seed than from roots. When propagating by division the roots may be cut into as many pieces as there are strong eyes. Each piece of root should have at least one eye or bud.

Planting.—In most sections of the North planting is usually done early in the spring although fall planting is practiced in the milder regions. Fall planting is advised where deep freezing does not occur, as in the regions from Maryland south as far as the crop can be grown. It does not thrive well in the South except at high altitudes. The pieces of roots are usually planted 3 to 4 inches deep in rows 4 to 6 feet apart and about 2 to 3 feet apart in the row. On very rich soils 3 by 5 or 3 by 6 feet distance should be used, especially for the Victoria variety which is more vigorous than the Linnaeus. The two varieties mentioned are the only important ones grown in the United States. The Linnaeus produces pink stalks of the best quality.

Cultivation.—Good, clean cultivation should be given throughout the season to keep down weeds and to maintain a soil mulch. Large amounts of water are used by the large leaves and stems, therefore moisture conservation is of great importance. Shallow cultivation should be given to avoid injuring the roots. Hand hoeing is necessary to keep down weeds in the row. It is important to get a good growth after the harvesting season since a large part of the spring crop is produced from reserve food stored in the roots or crowns during the latter part of the preceding season. The seed stalks which appear should be broken off as these take food which should go to the roots.

Harvesting.—In order to produce strong roots the plants are allowed to grow 2 years before any crop is harvested. During the third season from planting the harvest period should be short (4 to 5 weeks) but after this the period may be extended to two months, if the stalks continue to be of good size. Harvesting in late summer is not advised since removing the leaves and stalks at this time weakens the roots. In harvesting the largest stalks are pulled (not cut) and the leaf blades are at once cut off to prevent wilting of the stalk.

The rhubarb stalks are usually bunched and tied, but when the price is very low they are sometimes sold in bulk. When bunched, from two to eight stalks are tied together, the number depending upon the market. In some markets rhubarb is sold by the pound while in others it is sold by the bunch. Rhubarb is sold mainly on local markets and is hauled in wagons or trucks without being packed. In Southern Illinois rhubarb is grown on quite a large scale for shipping to Chicago and other markets and is packed in crates or boxes made especially for the purpose.

ARTICHOKE

The artichoke, or globe artichoke (*Cynara scolymus*) is a perennial plant grown for its flower head or flower bud. It is a coarse, thistle-like plant of the sunflower family, native of the Mediterranean region and common in the wild form in Southern Europe and in a portion of Asia. This vegetable is highly prized in France and in some other Euro-

pean countries, but has not become popular in the United States although it has been grown to a limited extent in the South for over a hundred years.

The artichoke is tender and will not thrive, without winter protection, in regions where the temperature goes much below freezing. It is grown for home use to a very limited extent in sections of the South Atlantic and Gulf Coast states. As a market crop it is produced in sections of Southern Louisiana, below New Orleans, and in California, in the vicinity of Tobin and Half Moon Bay south of San Francisco. The artichoke can be grown in the colder regions if the plants are given good protection.

The artichoke is a heavy feeder therefore should be planted on good rich soil and liberally manured. Stable manure is usually used in large quantities and in addition commercial fertilizers are often applied.

Planting.—The artichoke can be grown quite readily from seed but the plants do not come true, therefore, propagation by suckers is the more common method. In a well-cared for bed many suckers develop around each plant and since it is advisable to leave only a few there is always an abundance of material for starting new plantings. Where seeds are used to start a bed only the best plants should be selected. These can be used to increase the planting by using the suckers.

The distance of spacing varies considerably, depending upon the richness of the soil and on the method of culture. Ordinarily the rows are 4 to 5 feet apart with the plants 2 to 3 feet apart in the row. In California the planting distance is greater than this, the rows being 6 feet or more apart.

While the artichoke is perennial the planting should be renewed every 2 or 3 years.

Cultivation and Care.—Clean cultivation should be given throughout the growing season since a large amount of moisture is required to produce a crop.

In regions where severe freezing occurs some covering is necessary. Manure has usually been recommended, but Wellington (174) tried manure at Geneva, New York, with disastrous results to the plants. On this he reports:

> Fresh horse manure was tried on the Station beds but with disastrous results in that, either by heating or by retaining too much water, it caused the heart of the crowns to rot, with consequent death to the plant. Coal ashes were then used with success. The foliage is semi-hardy and should not be covered until late in November, and the covering should be removed in spring, in late March or early April. Before mounding with ashes the leaves must be cut back to within a foot of the ground and drawn in about the crown.

Harvesting.—The flower heads or burs, as they are sometimes called, should be harvested while they are young and tender. They are cut

with an inch or two of the stem attached, and for market theyare graded and packed in drums, or special boxes.

JERUSALEM ARTICHOKE

The Jerusalem artichoke (*Helianthus tuberosus*) is a perennial plant belonging to the Compositae or sunflower family. It is a native of North America, probably of the Mississippi Valley, and was cultivated by the Indians at the time the early settlers arrived in the United States. The Jerusalem artichoke is grown for its tubers, which resemble potatoes.

Large yields of Jerusalem artichoke have been secured. Newman (107) reports 544 and 540 bushels to the acre at two locations on the grounds of the South Carolina Agricultural College. He reports that while every effort was made to remove all of the tubers from the ground yet those left came broadcast over the land the next spring. A good method of getting rid of the tubers left in the soil is to turn hogs into the patch.

The Jerusalem artichoke is propagated about the same way as potatoes, the tubers being planted whole or cut. The rows are spaced about 4 feet apart, pieces or whole tubers being dropped 18 inches apart and covered about 3 inches deep.

The tubers are boiled and used like potatoes and are also highly esteemed as a salad. It is not a common practice to dig and store the crop in the South, since it keeps better in the ground. Because of the large yield the Jerusalem artichoke is a cheap hog food and when grown for this purpose there is no expense of harvesting since the hogs will root them out if given the run of the field.

SEA-KALE

Sea-kale (*Crambe maritima*) is a hardy perennial of the Cruciferae or mustard family, native of Western Europe. It is grown for its young leaves and shoots, which are blanched with earth or with a sea-kale pot. A large flower pot, with the hole in the bottom plugged, will serve the purpose of a regular kale pot.

Sea-kale may be propagated by seeds or by cuttings. When seeds are used they are planted in a well-prepared seed bed to the depth of about one inch. After the plants are well up they are thinned to 5 or 6 inches apart in the row and given good cultivation and care during the season. The following spring they are taken up and planted in the permanent bed. When cuttings are used pieces of roots 4 to 5 inches long are planted in their permanent location early in the spring, spacing them 3 feet each way.

The bed should be well fertilized each year, either with manure or with chemicals. The care of the bed should be about the same as described for rhubarb. At the close of the season the dead leaves are

cleared away and the crowns of the plants are covered with a mulch of compost or manure.

Shoots from plants which have made a strong growth may be harvested for a short period during the second season, but a full crop should not be taken until the plants are three years old. The young shoots are cut when 4 to 5 inches tall and used much in the same manner as asparagus. The cutting season usually lasts 3 to 6 weeks. This vegetable is very popular in England but is little grown in the United States.

UDO

Udo is a rank-growing perennial of the Araliaceae or ginseng family and is probably a native of Japan, where it is grown for its succulent shoots. It has been known to nurserymen in this country for 25 to 30 years under the name *Aralia cordata* Thunb. Within the past 10 or 15 years it has been grown experimentally in America as a food plant. The plant dies down in the fall after the first frost and comes up again in the spring. It grows to a height of 10 feet or more in rich soil, producing a mass of large, green leaves and long, loose flower clusters, sometimes 3 feet in length.

Culture.—On the culture of udo, Fairchild (45) gives the following:

As a home garden vegetable the experience of the past 10 years indicates that the udo, when once started, is a very easy plant to grow. Amateurs have experienced some difficulty in growing udo from seed, but anyone with greenhouse or cold frame facilities should have no difficulty with fresh seed, if it is sown ¼ inch deep in March or April in what is known as potting soil, consisting of 1 part loam, 1 part leaf soil or mold, and 1 part sand. In two or three weeks the seeds should be up. From the flats seedlings can be planted out in the ground as soon as thy are 3 or 4 inches high, or they can be potted off and later set out in the field. Seedlings started in boxes or flats in March will often grow 4 or even 6 feet tall the first year and will flower freely if not prevented from doing so, as they should be, by cutting or pinching out the round flower buds in midsummer. . . .

The udo is a coarse feeder, with great succulent roots which travel rapidly through loose rich soil. They can consume astonishing amounts of nitrogenous manures and turn them into succulent shoots. Planting udo on poor, dry lands is not recommended, for, though it would probably live, it would make no growth there. . . .

Three and a half feet apart is close enough for plants of the udo to stand, for as they grow older the crowns become at least a foot across. On very rich soil the writer has found 4 feet not too great a distance. When grown even with this space between them the plants will touch each other and make horse cultivation impossible in late summer.

Seedling plants have often produced by the following spring roots large enough to give a small crop of shoots, but it is advisable to delay cutting until the second year in order not to weaken the plants at first. . . .

The udo has done best in the moist regions of the country, especially in the New England states, Canada and the Atlantic Coast states as far south as the Carolinas, in the rainy region of Puget Sound and in the trucking sections of California, about Sacramento. The fact that it dies down in the winter and can be covered makes it possible to grow it where temperatures go far below zero. A temperature of −17 degrees F. for a few days has not injured it in the least.

Blanching.—The green stems of the udo are rank in flavor and are usually blanched for use as food. On light, muck soil near Antioch, California, according to Fairchild, excellent udo has been produced by mounding up the hills with soil as is done with asparagus in the same region. On heavy soils this method is not satisfactory as the shoots are slow in coming through. The use of large drain tile, which has one end plugged with cement is recommended by Fairchild for blanching udo in a small garden. Another method suggested is to use a deep box or small half cask from which the bottom has been removed and fill it with sand or such light material as sifted coal ashes.

Shoots of udo produced from 3-year old plants should be 12 to 18 inches long and 1 inch or 1½ inches in diameter at the base.

Preparation for the Table.—Fairchild (45) states that the flavor of udo is distinctly aromatic.

When properly prepared it is one of the most delicious of vegetables, but unless properly cooked it is sure to meet with ridicule. The reason for this lies in the fact that its stems contain a resinous substance which gives them a decided flavor of pine when tasted raw.

It is a simple culinary practice to boil strong-flavor vegetables in two (or even three) waters, and this is advisable as a general recommendation, although when used for soup it does not appear to be always necessary. An hour's stay in ice water will remove the resin from the shoots, provided they are cut into thin slices or shavings.

He suggests the following recipes:

Udo on Toast.—Peel the shoots and drop them into cold water. Cut them into 4-inch lengths. Boil them in salt water for 10 minutes, then change the water, adding a fresh quantity of salted water and boiling until quite soft. Prepare a white sauce, such as is used for cauliflower or asparagus, put the udo in it, and allow it to simmer until thoroughly soft. Serve on toast in the usual way. If there is too much of the pine flavor, as there may be if the shoots are not thoroughly blanched, a second change of water will remedy this.

Udo Salad.—Peel the shoots, cut them into 3-inch lengths, and then split them into thin shavings, letting these fall into ice water as they are made. Allow them to soak in the water for a half hour or an hour, so as to remove the resinous material in them. Serve with a French dressing of pepper, salt, oil, and vinegar. Do not dress the shavings until just before serving, as they become stringy on standing in oil.

Udo Soup.—Remove the skin from the shoots. Cut in pieces one-half inch long and wash thoroughly in cold water. Cook until tender and mash through a colander. Add a pint and half of milk, one-half pint of cream, two tablespoonfuls of butter, and one tablespoonful of flour, mixing the flour and butter until smooth. Season with pepper and salt. (Recipe for one bunch of udo; enough for five persons.)

CHAPTER XVIII

POTHERBS OR GREENS

Spinach	Kale
New Zealand Spinach	Mustard
Orach	Collards
Chard	Dandelion

Potherb crops are grown for their foliage, therefore, they must make rapid growth in order to be crisp. All of the crops discussed in this chapter are of easy culture and are in greatest demand in the spring and fall. In fact, chard and New Zealand spinach are the only crops in this list which thrive during the warmer portion of the growing season, the others being grown as early spring and late fall crops in the North and mainly as winter crops in the South.

To the plants listed many others might be added. Some crops used for greens such as turnips, beets and sea-kale are discussed in other chapters. Many wild plants such as dandelion, several species of docks, lambs quarter, wild cress, poke-weed, milk-weed and others are used as greens.

The need for green food has been greatly emphasized during recent years due to the increase in knowledge of the value of the essential salts found in green plants, and especially because such plants are rich in vitamins.

SPINACH

Spinach is the most important of the potherbs grown in the United States and it is increasing in popularity each year. According to the 1920 Census Report, 10,027 acres were grown for sale in 1919 and the value was $1,715,869. The value per acre was $171. The growth of the industry from 1918–19 to 1920–21 is illustrated by the carlot movement during these three years as reported by the U. S. Department of Agriculture, April 1, 1922. Table XVIII gives the carlot movement from the important producing states and the total for all states.

The increase in production of spinach is probably due to the fact that its importance in the diet is becoming better understood. Spinach is rich in iron and is said to be rich in vitamins. The use of spinach in children's diet is advocated by dieticians and physicians.

TABLE XVIII.—CARLOT SHIPMENTS OF SPINACH 1918–1921

States	Season of		
	1918–19	1919–20	1920–21
California	283	321	145
Maryland	1	215	346
Missouri	195	3	259
Texas	979	934	1,459
Virginia	1,431	902	2,444
Total	2,913	2,396	4,705

History and Taxonomy.—Spinach is a native of Asia and was probably introduced into Europe in the twelfth or thirteenth century. It was known in America early in the nineteenth century, but there are no records showing when it was introduced.

Spinach is an annual plant belonging to the Chenopodiaceae or goosefoot family and is therefore closely related to the beet. The genus Spinacia contains only a few species. The two types of spinach, prickly-seeded and smooth-seeded are considered by some authorities as belonging to the same species, while others consider them two species. Spinach is mostly dioecious and after flowering the male plant usually dies, while the female plant continues to grow and ripen its seed.

Soil Preferences.—Spinach can be grown on any good soil, but for an early spring crop a sandy loam is preferred and this type is also used for the fall crop. Rich loams and silts are also considered good for this crop. In some sections of the North, spinach is grown to a considerable extent on muck soil and this is considered excellent, especially when the crop is grown for canning. When the crop is grown on muck soil there is less grit in the canned product than when the crop is produced on mineral soils. The soil for spinach should be rich and fairly moist but well drained.

In the Norfolk, Virginia, region where spinach is grown on a large scale as a winter crop the soil is thrown up into low flat beds 5 to 6 feet wide with a space 18 to 24 inches wide between the beds. The use of beds is mainly for the purpose of drainage since the land is flat. The soil should be thoroughly prepared as for any other small cultivated crop.

Manures and Fertilizers.—The soil should be well supplied with humus, therefore, either manure or a green-manure crop is important. However, it is best to apply fresh manure to some crop preceding spinach on account of weed seeds. In the Norfolk region commercial fertilizer is used on spinach and a heavy application is considered desirable. Fifteen hundred to 2,000 pounds to the acre of fertilizer containing

8 to 10 per cent ammonia, 5 to 6 per cent phosphoric acid and 2 to 4 per cent potash is quite common. Some growers use as much as 2,500 pounds of high-grade fertilizer to the acre, but it does not seem possible that this amount could be used. At the Rhode Island Station the residues from 16 tons of manure and ¾ ton of a 4–10–2 fertilizer, applied to tomatoes in the spring, plus ½ ton of a 4–7–6 fertilizer applied to the spinach has produced a considerably higher yield than the residue of 32 tons of manure applied to tomatoes in the spring. By adding nitrogen to the fertilizer applied to the spinach the yield was increased 25 per cent over the manure treatment. The fertilizer plus extra potash increased the yield 21 per cent over 32 tons of manure applied to the tomatoes, which preceded the spinach. (See Table IV.) On muck soil a mixture containing 2 to 4 per cent ammonia, 8 per cent phosphoric acid and 8 to 10 per cent potash is often applied at the rate of 1,000 to 1,500 pounds to the acre.

In the vicinity of Norfolk, Virginia, it is the common practice to apply the fertilizer in several applications (three to five) during the growing season. On light, porous soils it may be desirable to apply the fertilizer at intervals during the period of growth rather than to apply all at one time, but it is doubtful if this is necessary on most soils.

Planting.—Spinach is planted for a winter crop in the South and in California, while in most other sections it is planted mostly for fall and early winter use although early spring planting is practiced to a considerable extent. For the fall crop the seed may be planted from July to September, depending upon the locality. Spinach is hardy and will withstand quite severe freezing, if it is well established before cold weather occurs. For the spring or early summer crop the seed should be planted as soon as the soil conditions will allow. In the vicinity of Buffalo, New York, spinach seed is often planted early in March.

In the home garden spinach seed is usually planted by hand, but in commercial plantings seed drills are used. Gang drills, four or more drills attached to a common frame, are used by growers in many sections. At Norfolk, Virginia, the rows are spaced 10 inches apart, while in many other sections the spacing is 14 or 15 inches to allow for hand cultivation with wheel cultivators. The amount of seed varies with the spacing of the rows, 15 to 30 pounds to the acre being used. Most growers sow about 20 pounds.

Thinning.—After the spinach plants have become well established they are thinned to stand about 4 to 6 inches apart. In some sections this is done with a long handled spoon and is called "spooning out." In other regions the plants are thinned with a narrow hoe. Some hand work is necessary to remove plants that are very close together. In the home garden the young plants removed in thinning are usually used as food.

Cultivation.—Clean shallow cultivation is given spinach, and this is accomplished with hand cultivators, or with horse-drawn implements. On muck soils the scuffle hoe and the wheel hoe with the blade attachments are used to a considerable extent. At Norfolk, Virginia, novel weeder-like cultivators are sometimes used and one horse or one mule pulls two of the implements as shown in Fig. 11. The horse or mule walks in the space left between the beds so that there is no danger of injuring the plants by tramping on them.

Fig. 11.—Two cultivators fastened together for use in cultivating spinach on raised beds in the vicinity of Norfolk, Virginia. (*Courtesy of Virginia Truck Experiment Station*).

Varieties.—Kinney (83) classified the varieties of spinach into four groups as follows:

Group 1. Norfolk or Bloomsdale Spinach. Plants more or less vase-form, leaves broad, thick and supported by their stalks so that they do not naturally rest upon the ground. Blossom stalks appear at an early date.

Bloomsdale and Norfolk Savoy are important varieties belonging to this group.

Group 2. Round-leaved Spinach. Plants compact in habit of growth with leaves conspicuously rounded in outline and formed close to the ground. Tissue firm, color dark green, blossom stalks formed rather tardily. A slow-growing spinach as compared with the other types.

Victoria is probably the best known variety belonging to this group.

Group 3. Thick-leaved Spinach. Plants large, leaves long and spreading out upon the ground, ends and lobes of leaves pointed. A highly-prized type of spinach both for spring and fall planting on account of large size and rapid growth.

Viroflay, Thick-leaved Round and Eskimo or Giant Thick-leaved belong to this group.

Group 4. Prickly Seeded Spinach. Plants variable, leaves often with long, slender stalks and rather narrow blades. Seed with horn-like projections.

Varieties in this group are supposed to be more hardy to cold than those in the other groups. The best known variety is Prickly Seeded or Winter.

The varieties of spinach most commonly grown in commercial plantings are Bloomsdale, Viroflay, Savoy, Victoria and Giant Thick-leaved, Prickly Seeded or Winter is grown to some extent, but is discriminated against on the market on account of its appearance.

Two other groups (5) New Zealand spinach and (6) Mountain spinach or Orach are given by Kinney, but since these do not belong to the genus Spinacia they are discussed under their own names.

Spinach Blight or Mosaic.—The most serious disease of spinach is blight or mosaic which is very destructive in many regions, especially in Virginia. Plants affected by this disease show a slight yellowing and malformation of the young leaves in the early stages. In later stages the plant stops growing and the leaves are mottled. Some of the older leaves may turn brown and wither. Leaves of plants affected with mosaic are slightly brittle and the blade curves backward toward the base of the plant.

McClintock and Smith (91) have shown that the disease is carried from diseased to healthy plants by insects, especially the aphis. It was thought that spraying to control this insect would control the mosaic, but destroying the insect has not proven practicable.

Development of a mosaic-resistant strain seems the most promising means of control of this disease. Work on this problem has been underway at the Virginia Truck Experiment Station for several years and a strain has been developed which is claimed to be quite resistant. Smith (138) reports that the strain produced by crossing a type secured from Manchuria by F. N. Meyer with Savoy, Round Thick-leaf Winter, Flanders and Long Standing has resulted in the production of a disease-resistant variety which has been named Virginia Savoy. At the Virginia Truck Experiment Station only 0.64 per cent of the Virginia Savoy plants were affected with mosaic in the autumn of 1920, while in adjacent beds 10.57 per cent of the commercial Savoy was affected.

Spinach Aphis (*Myzus persicae*).—This insect is a pale yellowish-green plant louse that often causes serious injury to the spinach crop. It injures the spinach by sucking the juice out of the leaves and also carries spinach blight from diseased to healthy plants. Since this insect lives largely on the underside of the leaves it is very difficult to control by spraying. It is claimed by Smith (138) that the Manchuria spinach is distasteful to the spinach aphis, and that these insects are much less abundant on the Virginia Savoy than on the commercial Savoy.

Dusting with hydrated lime containing 2 to 3 per cent nicotine gave fairly good control of plant lice on spinach and other crops at the Virginia

Truck Experiment Station (190). The quantity of dust required varied from 20 to 40 pounds to the acre. Based on an average of four species of plant lice 2 per cent nicotine dust killed 82 per cent of the insects and 3 per cent killed 89.3 per cent.

Beet Leaf Miner (*Pegomyia hyoscyami*).—This insect is a serious pest of early spinach in many sections of the United States. For discussion see under "Beet."

Harvesting.—Spinach may be harvested from the time the plants have five or six leaves until just before the seed stems develop. Of course, a larger yield is secured if the plants are allowed to develop to full size than if cut when they are small. Medium to large sized plants are preferred, if the leaves are tender. In commercial plantings two or more cuttings are sometimes made, the largest plants being cut first.

Fig. 12.—A home-made tool for cutting spinach.

Spinach should be harvested by cutting the tap root just below the lower leaves. The cutting may be done with a long, sharp knife, with a hoe, with the blades of hand cultivator or with a special home-made tool similar to the one shown in Fig. 12. This tool has a long handle with a cross-piece on the end and is pushed in front of the operator like a lawn mower. Spinach is often gathered with forks and placed in large crates, or large baskets which are loaded on wagons, or it may be loaded in bulk in the wagons. Placing the spinach in baskets or crates is preferable to loading in bulk, since by the latter method extra handling with forks increases the injury.

Some trimming is usually necessary to remove all of the dead and discolored leaves. This may be done in the field or in the packing shed. If the crop is grown for the cannery the trimming is done at the factory.

It is best not to cut spinach immediately after a rain or a heavy dew because the leaves are crisp and brittle and break easily when wet. A slight wilting will prevent any breaking of the leaves.

Preparation for Market.—Spinach is often washed to remove sand and dirt and to improve its appearance. For local markets there is no particular objection to this, but for long-distance shipment washing is often injurious. The plants are likely to be bruised and the leaves broken to some extent and decay is thereby increased. Ridley (123) found that washed spinach developed a greater amount of decay after holding 10 days under approximate transit conditions than unwashed spinach held under the same conditions. The lots which were washed developed 37.3 per cent soft rot, while those not washed developed only 7.7 per cent In shipping tests, where the period in transit was from 3 to 6 days, the soft rot found in washed spinach on arrival was 5.5 per cent and in unwashed spinach 0.0. Three days later the washed spinach showed 24.8 per cent decay and the unwashed 5.7 per cent.

Spinach is packed for shipment in various types of packages including the round bushel basket, barrel, hamper and crate. For long-distance shipping, as from California, Texas and Louisiana crushed ice is put in the package. As a rule the amount of ice used is from two-thirds to three-fourths of the weight of the spinach. When baskets are used the common practice is to put the ice in the center. In icing barrels the ice is usually distributed in three or four layers. Ridley (123) has shown that when part of the ice is put on top of the spinach much better results are secured than when all of the ice is placed in the center of the basket. In one car shipped from Austin, Texas to Chicago temperatures of the spinach were taken above and below the ice at frequent intervals during the trip. The temperature below the ice averaged about 35 degrees F. for three and a half days, while above the ice the temperature at the beginning was above 60 degrees F. and gradually dropped to about 42 degrees F. The average difference was over 10 degrees for the transit period.

NEW ZEALAND SPINACH

New Zealand Spinach (*Tetragonia expansa*) is not a true spinach but belongs to a different family, Aixoaceae. The leaves resemble spinach leaves to some extent and the product is used in the same way. The plants are much branched, spreading often 3 or 4 feet across, and grows to the height of 1 to 2 feet. The leaves are thick, dark green and somewhat triangular in form. The seeds are enclosed in a hard rough pod.

New Zealand spinach thrives in hot weather when ordinary spinach will not grow satisfactorily. It is not seriously injured by the leaf miner and does not go to seed quickly. The tips of the branches are harvested for food and since these do not come in contact with the soil there is no sand or soil to be washed off and no waste in preparing for the table.

Culture.—Seed may be planted in a greenhouse or hotbed during late winter. The plants should be pricked out while still small, preferably

into pots so that they can be set out later without disturbing the roots to any great extent. They should be set in the field 2 to 3 feet apart in the row, with the rows 3 to 4 feet apart. The seed may be sown directly to the field early in the spring and after the plants have become well established they should be thinned to stand a foot to 2 feet apart in rows 3 to 4 feet apart.

The general culture is about the same as for spinach.

Harvesting.—The tender tips of the branches 3 to 4 inches long are snipped off. Harvesting begins as soon as the plants get large enough and continues until they are ruined by frost. The main portion of the harvest period is during the summer when spinach is not available.

This crop is not grown for shipment to any great extent, but in the vicinity of New York it is quite important as a market garden crop and is handled in very much the same way as spinach.

ORACH

Orach or mountain spinach (*Atriplex hortensis*) has long been used as a kitchen garden vegetable in Europe, but is rarely grown in the United States. It belongs to the family Chenopodiaceae. The plants grow to the height of 4 or more feet and have many lateral branches. There are three types based on the color of the leaves. The white variety has pale green leaves. The green variety has rounder leaves than the white variety and is slightly more vigorous. The red variety has stems and foliage of dark red color. The color disappears when the leaves and stems are cooked.

The seed is planted in the open early in the spring in rows 18 to 24 inches apart and the plants thinned to stand 10 to 12 inches in the row. The plants are used while young and tender, and while they stand hot weather fairly well, they soon run to seed, therefore, for a continuous supply, successive plantings should be made at intervals of two weeks until summer weather arrives.

The general culture of orach is about the same as for spinach for which it is a substitute.

CHARD

Chard or Swiss chard (*Beta vulgaris* var *Cicla*) is a foliage beet which has been developed for its large, fleshy leafstalks and broad, crisp leaf blades. It is one of the best potherbs for summer use since it withstands hot weather better than most crops grown for use as greens. The leaves are prepared for the table like spinach, while the leafstalks and midribs are often cooked and served like asparagus. Chard is not as rich in iron as spinach, but is a good addition to the list of potherbs and deserves more general planting, especially in the home garden. It may be canned in the same manner as spinach.

Culture.—Chard is easily grown. The plants may be started in the greenhouse or hotbed and transplanted to the open as soon as the danger of hard frosts is over, or the seed may be sown in the garden or field where the plants are to grow. The rows should be about 18 inches apart for hand cultivation, and 24 to 30 inches for horse-drawn cultivators. When plants are set out they should be spaced 10 to 12 inches apart, and when seed is sown in the garden the plants are at first thinned to 3 inches and later when they begin to crowd they are thinned to 8 to 12 inches apart in the row. The plants removed are usually used as greens.

A planting made in the spring will produce greens throughout the season until hard freezes occur and with a little protection the plants will live throughout the winter. Any good garden soil is satisfactory for chard. Unless the soil is quite rich and well supplied with humus a medium application of manure is desirable. Where manure is not available a green-manure crop may be used to supply humus. In addition to manure an application of a little readily available nitrogen, and about 500 pounds of acid phosphate to the acre is advised. Where no manure is used about 1,000 pounds of a high-grade mixed fertilizer should be applied on most soils.

Chard is grown to some extent as a forcing crop in greenhouses.

Varieties.—There are only a few varieties of chard, the most important one being Lucullus, which has very large crumpled, dark green leaves, with greenish-white leaf stems. Giant Perpetual has broad light green leaves. Lyon, a new variety selected for its broad stem and midrib, is listed by some seedsmen. Large Ribbed White has broad, white stalks and white midrib. The varieties are not very distinct and it is probable that many of the names are synonyms, but Lucullus represents the type most commonly grown.

Harvesting.—The usual method of harvesting is to cut off the outer leaves an inch or two from the ground while they are still tender, using a large, sharp knife. Care should be taken to avoid injuring the bud.

When prepared for market the leaves are washed if they are dirty and are then tied in bunches of a pound or more. Chard is grown commercially mainly as a market garden crop for local markets.

KALE

Kale (*Brassica oleracea* var *acephala*) is one of the important potherbs grown in the home garden and in commercial plantings. In the vicinity of Norfolk, Virginia, it is grown on a large scale during the winter and early spring and is shipped to the large markets. According to figures compiled by the U. S. Department of Agriculture the average area devoted to kale in the Norfolk section during 1916, 1917 and 1918 was 1,967 acres.

Kale is hardy to cold but does not thrive in hot weather, hence it is seldom grown as a summer crop.

Kale has been under cultivation for a very long time. It was known to the ancient Greeks. Several varieties were described by Cato who lived about 200 B. C. It was known in the United States during the seventeenth century.

Many types of kales are known, but they all probably belong to the same species. The chief characteristics of all kales are that the plants do not form heads like cabbage nor produce edible flowers like cauliflower and broccoli. Some kales are grown as ornamentals, being variously curled and of beautiful colors.

Soils and Fertilizers.—Kale will thrive on any good garden soil, but a well-drained sandy loam is considered best. The soil should be well prepared as for any other vegetable crop.

Kale is a fairly heavy feeder and unless the soil is rich it should be liberally fertilized. In the Norfolk, Virginia region growers apply a ton or more high-grade fertilizer per acre, and in some instances manure is also applied. If manure is not used some green-manure crop is turned under to maintain the humus supply. The green-manure crop is usually grown after an early crop of vegetables has been removed, since kale is not planted until late summer or fall. Fertilizer experiments at the Virginia Truck Experiment Station (*Bull.* 9) have shown the importance of phosphorus on the sandy loam soil used for kale in that region. Plats treated with large amounts of nitrogen alone, potash alone, and the two combined produced no crop while those to which phosphorus was added produced a fair yield even without manure, or other humus-forming material. Adding humus either in the form of crimson clover, or manure increased the yield with all combinations of fertilizers, and lime added to the clover and manure plats increased the yield over similar plats without lime. Crimson clover and lime in combination with complete fertilizers, gave as good results as manure and lime plus the same complete fertilizers. The crimson clover-lime treatment was much cheaper than the manure-lime combination. In general the experiments indicate that production can be maintained by the use of commercial fertilizers, lime and green manure crops.

On a good sandy loam soil 1,000 to 1,500 pounds of a 4–8–4 or 5–10–5 fertilizer should be sufficient even without manure, provided the humus is supplied by turning under green-manure crops. Where manure is used an application of 150 to 200 pounds of nitrate of soda, to give the crop a quick start, and 500 to 750 pounds of acid phosphate should be sufficient.

Planting.—Kale is grown as a fall, winter and early spring crop in the South and the seed is planted in late summer and fall. In the North the crop is grown either in the fall or in early spring. Seed for the fall

crop is planted in July and August depending upon the locality, elevation, etc. Spring planting should be done as early as the soil can be prepared.

Seed is sown with a seed drill and the rows are spaced 18 inches apart for hand cultivation and 24 to 30 inches apart for horse culture. After the plants are well established they are thinned to stand about 6 inches apart. When grown for home use the plants removed in thinning are usually used as food.

Cultivation and Care.—Clean cultivation is given kale and the general care is about the same as for spinach.

Kale is attacked by the same insects as cabbage, especially by the false cabbage aphis (*Aphis pseudobrassicae* Davis), the true cabbage aphis (*Aphis brassicae* Linn), the cabbage worm, the cabbage looper, and the harlequin cabbage bug. The same spray treatments suggested for the control of these insects on cabbage will control them on kale, but for successful kale spraying a specially rigged sprayer should be used. The nozzles should be near the ground and arranged in such a way that two of them spray the same row so that the material strikes the plants from the sides. According to Zimmerly and Smith (191) the cost of spraying kale with a power machine, covering six rows at a time was only $2.07 per acre for one application of arsenate of lead. With nicotine sulphate and soap the cost was $3.46 per acre for one application. These figures are for spraying kale in 20-inch rows. The cost was a little less where the rows were farther apart.

Varieties.—The varieties of kale grown in the United States belong to two groups, Scotch and Siberian. The foliage of the former is grayish-green in color and very curled and crumpled while that of the Siberian is of a bluish-green color and curled but not quite as much as the Scotch. Both dwarf and tall forms are grown, but the former is the more popular. The most common varieties are Dwarf Curled Scotch or Norfolk, Early Curled Siberian, Tall Scotch and Dwarf Green Curled.

Harvesting.—For home use the leaves are often picked from the plant, while for market the entire plant is cut off near the ground using a large knife. The discolored and injured leaves are removed and the plants packed for shipping without washing. In the Norfolk, Virginia region kale is packed in barrels for shipping to the northern markets.

MUSTARD

White mustard (*Brassica alba*) is grown for salad and greens to some extent, but has been replaced largely by spinach and kale. This plant is a hardy annual of the Cruciferae family. Seed is sown very early in the spring for spring use and in the fall for a winter crop. The plants go to seed quickly in the spring. The seed is sown thickly in drills 12 to 15 inches apart and the plants thinned as they crowd in the row. The White London is one of the well-known varieties of this species.

Giant Curled and Ostrich Plume are varieties of *Brassica Japonica* grown to some extent in the South. Both of these varieties produce large curled leaves. The Ostrich Plume or Giant Ostrich Plume is the most important variety of mustard in some sections of the South.

Black mustard (*Brassica nigra*) is grown largely for its seed, which is made into the mustard of commerce. This type is grown to a large extent on the adobe soils in Santa Barbara County, California.

In the South mustard is grown to a considerable extent as a trap crop for the harlequin cabbage bug. It is planted near the cabbage or other crop to be protected and the bugs collect on the mustard plants. Plants and bugs are killed by spraying with pure kerosene or kerosene emulsion early in the morning when the bugs are inactive.

COLLARDS

Collards (*Brassica oleracea* var. *acephala*) in habit of growth, resemble kale and rape rather than cabbage. The plant does not form a head, but is grown for the rosette of leaves which grow at the top of the stalk. It often attains a height of 2 to 3 feet. It is not grown in the North since it is inferior in quality to cabbage and to many of the potherbs.

Collards will withstand much more heat than cabbage and are therefore used as a substitute for it during the summer. The plant is quite hardy to cold and will withstand the winter weather in most parts of the South.

The crop is grown mainly for use as greens during the winter and its flavor is improved by a touch of frost. The seeds are sown in beds in the spring and in the fall, and the plants are transplanted to rows 3 to 3½ feet apart and 2 feet apart in the rows. The cultivation and care given collards are about the same as that given cabbage.

DANDELION

The wild dandelion is a great favorite for spring greens. It is cut from meadows and lawns for this purpose. It is considered a noxious weed in lawns and in meadows, since it drives out grasses and other plants.

The dandelion has been improved in size and vigor by culture and is grown to a considerable extent as a potherb in Europe and in a small way in the United States. Some of the varieties or strains resemble endive. The cultivated dandelion has been developed from the wild species, *Taraxacum officinalis,* a member of the Compositeae, or sunflower family.

Dandelion seed is usually sown in the place where the crop is to mature, although the plants may be started indoors and transplanted to the garden in the spring. The plants should stand 10 to 12 inches apart in the row with the rows 15 to 18 inches apart for hand cultivation.

A sandy or light loamy soil is preferred. The crop is usually harvested like spinach. The plants are sometimes blanched by tying the leaves together, or by covering to exclude the light.

Dandelion plants are sometimes forced in hotbeds or in greenhouses for winter and early spring markets.

CHAPTER XIX

SALAD CROPS

Celery	Parsley
Lettuce	Chervil
Endive	Cress
Witloof Chicory	Corn Salad

Salad plants in general thrive best during the cooler parts of the growing season, and to be of the highest quality growth must be quick and continuous. In the North these crops are grown mainly in spring and early summer or in late summer and fall, or at both seasons, since they do not thrive well during the hottest part of the growing season. In the South they are grown during the winter and spring.

Salad plants are appreciated now more than ever before because of the extension of knowledge of their value in the diet. They furnish roughage and at the same time are rich in some of the essential salts and in vitamins.

CELERY

Celery is one of the most popular of the salad crops grown in the United States, being exceeded in popularity only by lettuce. Until comparatively recent times celery was considered a luxury, but now it is a common article in the diet and is available practically throughout the year. It is prized for its crisp, piquant leaf stalks which are usually eaten raw. However celery is also used as a cooked vegetable and as flavoring in soups, dressings, etc.

Statistics of Production.—The commercial production of celery in the United States has increased from 15,863 acres valued at $3,922,848 in 1909 to 20,148 acres valued at $9,462,277 in 1919. The value per acre in 1919 was $470, which was nearly double that of the crop in 1909. This increase in the 10-year period indicates the increase in demand. In 1919 over three-fourths of the acreage of celery in the United States was produced in six states. California was in the lead with 5,351 acres and was followed by Michigan with 3,343 acres, New York, 3,288, Pennsylvania, 1,379, Ohio, 1,290 and Florida 1,225 acres. California alone produced over one-fourth of the crop. Celery is also grown to quite an extent in the home gardens, especially in the North, and this is not included in the figures given.

History and Taxonomy.—Celery is a plant of marshy places and according to Sturtevant, its habitat extends from Sweden southward to Algeria, Egypt, Abyssinia, and in Asia even to the Caucasus, Baluchistan and the mountains of India. It has been found growing wild in Terra del Fuego, in California and in New Zealand. The wild plant was probably used for medicinal purposes hundreds of years before it was used as food. There is no evidence that it was grown by the Ancients as a food plant, but if it was planted at all it was for medicinal purposes. The first mention of its cultivation as a food plant was in 1623 in France. The first cultivated celery differed little from the wild plant.

Celery is a biennial plant, although grown as an annual crop. It belongs to the family Umbelliferae. The flowers are very small, white, in compound umbels, among the leaves of the flower stalk.

Climatic Requirements.—Celery thrives best when the weather is relatively cool, especially at nights, and with a moderate, well-distributed rainfall of 8 to 12 inches during the growing season. The United States is naturally divided into four areas with reference to celery production: (1) The northern area, within which celery may be produced during the summer months; (2) the middle area within which the weather is too hot in summer and too cold during the winter for the successful culture of celery; (3) the southern area within which celery may be grown during the winter, and (4) California, where celery can be grown successfully in the fall and winter months. All of the areas are influenced by elevation and rainfall. In the middle area celery can be grown successfully at high altitudes as in the mountainous regions of Maryland, Virginia and West Virginia.

Soil Preferences.—The best soil for celery is a good type of well-drained muck and a large part of the crop produced in New York, Ohio, Michigan and California is grown on this type. Some of the crop produced in Pennsylvania, Florida and New Jersey is also grown on muck. Any good loamy soil will produce a satisfactory crop of celery if the weather and moisture conditions are suitable. A sandy soil, well supplied with humus is preferred to any other type of mineral soil, although celery can be grown on any rich well-drained soil. A heavy clay should be avoided if a lighter type of soil is available.

Some authorities believe that celery grown on muck soil is inferior in quality and has poorer keeping properties than that produced on mineral soils. There is no evidence available on which to base a comparison of keeping qualities of celery grown on different kinds of soil. Since most of the celery put in cold storage is grown on muck soil one would assume that such celery keeps fairly well. In the matter of quality the comparison is based on different varieties in most instances. Comparing the same variety grown on muck and on mineral soil at the same time and in the same locality the advantage, the author believes, is in

favor of the muck soil. To be of the best quality celery must have a continuous growth and this is more likely to take place on muck than on mineral soils due to the better physical condition and greater water-holding power of the former.

Preparation of the Soil.—Soil for celery should be given the very best of preparation in the way of deep plowing and thorough pulverizing. The soil should be deeply plowed in order to hold as much moisture as possible in the surface, since celery is not a deep rooted plant and is easily injured by drought.

In the North plowing in the fall is advisable for the early crop. Even for the late crop fall plowing is desirable. Fall-plowed land should be harrowed at frequent intervals during the spring until the crop is planted, in order to keep down weeds and to conserve soil moisture. In the South the land should be plowed long enough in advance of planting to allow ample time to pulverize the soil thoroughly. The time of plowing is determined to some extent by the previous use made of the land. If a cover crop is grown just ahead of the celery the land should be plowed long enough in advance to allow the material turned under to become partially decayed at least.

In preparation for planting the surface soil should be well pulverized by harrowing, disking and rolling or by whatever methods are necessary to make the surface fine. Just before planting the land should be rolled or dragged in order to secure an even surface for planting. The use of the roller or heavy drag is especially important on very loose muck soils, since packing is an advantage on such soils.

Manures and Fertilizers.—Celery is a heavy feeder and a rather poor forager, therefore, large quantities of fertilizers are usually applied. When mineral soils are used for growing this crop, manure is usually used in large quantities, especially in the North. In Florida dependence is placed on commercial fertilizer and soil-improving crops. Where manure is used it is advisable to apply some commercial fertilizer, especially some readily available nitrogen, such as nitrate of soda and also some phosphorus carrier as acid phosphate. Nitrate of soda 400 pounds and acid phosphate 400 to 800 pounds to the acre in addition to 20 to 30 tons of manure to the acre should be sufficient for the celery crop on mineral soils. Where manure is not used a ton of 5–10–5 fertilizer or some similar mixture should give good results if the humus supply is kept up. It is doubtful if more than a ton of 5–10–5 fertilizer could be utilized by a crop of celery. If a good crop is not produced with a ton of high-grade fertilizer per acre attention should be given to the physical condition of the soil and to other factors affecting growth of the crop.

On muck soils celery is fertilized almost entirely with commercial fertilizers since humus is abundant in these soils. In many sections growers use about one ton of a 4–8–10 fertilizer and this amount is prob-

ably the maximum that may be applied with profit. Since muck soils are deficient in potash a large amount of this element is considered necessary.

Results of experiments conducted at North Liberty, Indiana by the U. S. Department of Agriculture in cooperation with the Indiana Experiment Station indicate that all of the important fertilizing elements are of importance on this type of muck soil (10). The results for two years only are available, but since they are similar to those secured in other experiments they are given as indicating what might be expected. The soil on which these experiments were conducted is typical of the region and is similar to soils of other large areas in Northern Indiana and Southern Michigan. Table XIX gives the yields of celery under various treatments.

Table XIX.—Summary of Results of Fertilizer Experiments on Celery at North Liberty, Indiana—Crops of 1915 and 1916

Kind of fertilizer	Amount, lb. per acre	Yields per acre, lb.
Acid phosphate, 14 per cent	457	14,430
Mur ate of potash	200	19,881
Muriate of potash	400	24,704
Sulphate of potash	200	17,882
Nitrate of soda	200	19,161
Tankage	200	
Check (no fertilizer)	....	11,992
Manure	30,000	22,785
Limestone	2,000	13,645
Muriate of potash	200	24,186
Acid phosphate, 14 per cent	457	
Muriate of potash	400	27,562
Acid phosphate, 14 per cent	457	
Nitrate of soda	200	20,441
Tankage	200	
Muriate of potash	400	
Muriate of potash	200	26,870
Manure	30,000	
Manure	30,000	24,028
Limestone	2,000	

The figures in the above table show that potash gave a greater increase in yield than any other single element. Four hundred pounds of muriate of potash produced a little more than twice as much celery as the check plat and nearly as much as any combination. The only combinations outyielding the 400 pounds of muriate of potash were the acid phosphate-muriate of potash plat and the manure-muriate of potash plat. It will be noticed that all of these plats had the same muriate of potash treat-

ment. Acid phosphate alone and in combination with potash increased the yield. Nitrate of soda and tankage increased the yield considerably over the check plat but in combination with potash there is an apparent loss as compared to 400 pounds of muriate alone. This is not explained. Limestone gave only a slight increase over the check.

In other experiments conducted by the author, the results of which have not been published, 500 pounds of 16-per cent acid phosphate in combination with nitrogen and potash produced as large yield as 1,000 pounds of acid phosphate. In view of this it would seem that a ton of 4–8–10 fertilizer contains more phosphorus than is necessary. With this exception the common practice of using a ton of this mixture to the acre on celery would seem to be justified on the basis of experimental results. More than a ton has not been found to be justified.

Results of experiments with manure, fertilizers and green-manure crops on celery grown on a Miami silt loam soil at the Rhode Island Experiment Station are given in Chapter III. A larger yield of celery was produced by 16 tons of manure supplemented with chemicals than with 32 tons of manure alone. Where extra nitrogen was added to the regular fertilizer application the yield was still further increased. Extra potassium also considerably increased the yield while extra phosphorus gave a very slight increase.

Sowing Seed.—Celery seed is never planted where the crop is to grow to maturity, because of the care necessary to get a stand of good plants. The seeds are small and germinate very slowly and the plants are quite delicate when small so that special attention is necessary to get them started.

The time of sowing seed is determined largely by the time the crop is desired for use. Seed for the very early crop in the North is usually sown in January or February although some growers sow as late as March 1st. It is not desirable to sow seed any earlier than is necessary to get plants large enough for planting at the proper time since early sowing is probably the main cause of very early development of the seed stalks. Seed for the main or late crop of celery in the North is usually sown in outdoor beds late in April or in May. In the South celery is grown mainly as a winter and early spring crop and the seed is planted in late summer and at intervals during the fall. For the early winter crop the main problem in plant growing is to get the plants started during the hot weather of late summer and early fall. Partial shading of the seed bed is practiced in some localities.

Soaking the seed, prior to planting, hastens germination and is practiced by growers in many sections, especially for the late crop of celery. A common method is to moisten the seed in a pan or other receptacle and put it in a warm place where it is kept for several days or until the sprouts begin to appear. Another method followed by some growers is

to place the seed between folds of cloth. The cloths are kept moist. Care must be taken to prevent the seeds from drying out as this would injure their vitality. As soon as the sprouts appear the seeds should be planted because if the sprouts are allowed to grow too long there is danger of breaking them in planting. When ready for planting the seed is spread out in an airy place to dry, but complete drying should not be allowed. Many growers mix the seed with ashes, dust, corn meal or other substances to take up the moisture and to aid in distributing the seed.

Celery seed may be sown in rows or broadcast and both methods are used. Broadcasting gives a better distribution of plants but sowing in rows gives an advantage in watering, thinning and weeding. When plants are started in the greenhouse or hotbed the seed is sown broadcast, or in rows about two inches apart and covered with pieces of burlap or with about one-eighth of an inch of soil. Sometimes the burlap covering is used even when the seed is covered with soil. The burlap prevents washing the seed into piles when watering and also prevents rapid drying of the surface of the soil. As soon as the seedlings appear the covering should be removed to prevent injury to the plants. When the seed is sown in outdoor beds broadcasting is sometimes practiced and the beds are covered with burlap. Sowing in rows 12 to 18 inches apart, using a seed drill for the purpose is popular in some sections. By this method the plants can be kept well cultivated with hand cultivators. Thinning can be more easily done when the plants are grown in rows.

When the plants are grown in the greenhouse, and are transplanted prior to setting in the field, $\frac{1}{4}$ pound of seed is sufficient for one acre planted in single rows 3 feet apart. When the seed is sown in outdoor beds, and the plants are taken direct from the seedbed to the field it is advisable to sow $\frac{1}{2}$ pound for each acre to be planted.

Care of Plants.—Very close attention to watering is necessary before the seeds germinate and while the plants are small, especially when grown in the greenhouse or hotbed. The surface of the soil should never be allowed to dry out until the plants become well established, but keeping the soil soaked should be avoided. When this method of planting is used the weeds should be kept under control and the soil kept stirred between the rows.

Plants for the very early crop are often transplanted before time for setting in the field. This is usually done 4 to 6 weeks after the seed is sown. They may be set into flats, or into the soil of the hotbed or greenhouse, spacing the plants $1\frac{1}{2}$ by $1\frac{1}{2}$, or 2 by 2 inches. This transplanting is usually done as soon as the plants reach sufficient size, $1\frac{1}{2}$ to 2 inches tall. (See Chapter VIII.)

For a large portion of the acreage planted the plants are taken direct from the seed bed to the field, since transplanting is very expensive and is of little advantage except for the very early crop.

Setting the Plants.—Before taking up the plants for setting in the field the plant bed should be watered, preferably a few hours in advance of lifting the plants. This is especially desirable with plants that have been transplanted, as the watering will make the soil adhere to the roots. It is desirable to set the plants when the soil is moist and the air rather humid, as there is less wilting of the foliage under these conditions than when the soil and air are dry. When it is necessary to plant in a dry soil it is desirable to water the plants after they are set, or to moisten the soil along the row before setting them. A common practice on muck, when the soil is dry, is to pour a stream of water, from a watering can, along the row where the plants are to be set. After the water has soaked into the soil the plants are set, and, under most conditions, there is little loss of plants. On mineral soils the more common practice is to apply the water after setting the plants.

Celery plants are set 4 to 6 inches apart in the row, with the rows 12 to 18 inches apart in close culture, and 3 to 5 feet in the ordinary method, followed by most growers. Plants are sometimes set in double rows 6 inches apart each way with the sets of rows 3 to 5 feet apart. This practice is not as common as it was formerly. The main objection to it is that it is difficult to cultivate between rows 6 inches apart and the work must be done by hand. On muck soil 3, 3½ and 4 feet between the rows are the most common distances. For blanching with boards 3 feet apart is sufficient but where soil is used for blanching the distance should be greater. The approximate number of plants required to plant an acre at various distances is given in the following table.

Table XX.—Number of Plants Required to Plant an Acre at Varying Distances

Distance between rows, in. or ft.	Distance between plants, in.	Number of plants
18	4	87,000
2	4	65,240
3	4	43,560
4	4	32,670
5	4	26,160
3	5	34,848
3	6	29,000
4	5	26,240
4	6	21,780

Celery plants are set by hand since machine planters are not adapted to such close planting. In addition to this, celery plants must be set at a certain depth and this would be very difficult with a machine. The

plants must be set deep enough to prevent drying of the roots, but not so deep as to cover the heart or growing point. Setting plants in a trench is not desirable on account of the danger of the growing point being covered with soil in cultivation. Transplanted plants of good size may be planted in a shallow furrow opened with a small hand plow. Non-transplanted plants are usually planted in an opening made with the forefinger, or with a dibble.

In planting celery it is very important to have straight rows equal distance apart for convenience in spraying and blanching. The use of a line, or a marker is advisable. A common practice on muck soil is to set a line at the proper place and press it into the soil with the back of a shovel. Another method is to use a sled marker with a small strip of iron on the runners. This is especially good when the soil is dry as the runners push the dry soil aside and the small strip of iron usually makes a groove into which the plants are set. This small groove is especially desirable when the soil must be moistened before or after setting the plants, since only a small amount of water is necessary to moisten the soil in the groove.

Cultivation.—Good, clean cultivation throughout the growing season is important for the celery crop since weeds are very troublesome on most celery soils. Cultivation of celery is very important also from the standpoint of maintaining a soil mulch, since the roots do not have much spread. (See Chaper X.) Cultivation should begin as soon as the plants are set as there is considerable packing of the soil in planting. While the plants are small, hand cultivators are used near the row since a horse cultivator if run close would throw soil over the plants. The middles of the rows are cultivated with horse cultivators when the rows are far enough apart. Under "close culture," hand cultivation only is given.

When weeds are troublesome the knife attachments are usually used on the hand cultivators although small disks are often used when the plants are small. When the disks are used the row is straddled with a two-wheel cultivator, one set of disks running on each side of the row. These disks throw the soil away from the plants and leave them on a little ridge, which is leveled down in hand weeding. The disks are usually employed only in preparation for hand weeding.

In all cultivation the surface soil should be left as level as posible, therefore it is desirable to use small-toothed cultivators. Shallow cultivation is desirable at all times especially near the plants as many of the roots grow very near the surface and within 6 to 12 inches of the row.

Blanching.—The blanching of celery results in the loss of the green coloring matter and the strong flavor, and makes the leaf stalks crisp and tender. Blanching is accomplished by excluding the light from the leaf stalks while the plants are still growing.

Several methods of blanching are employed including the use of boards, paper and soil. Boards and paper are used almost exclusively for blanching early celery, since it is not safe to use soil during hot weather. Celery banked with soil is likely to rot when the weather is hot. The late fall crop is commonly blanched by banking with soil, since this is the cheapest method and the soil is a better protection against cold than either boards or paper.

Boards used for blanching celery are usually 1 inch thick, 10 to 12 inches wide and 14 to 16 feet long. A good grade of hemlock is considered quite satisfactory although other kinds of woods are used. A light-weight durable wood is desired. In placing the boards they are first

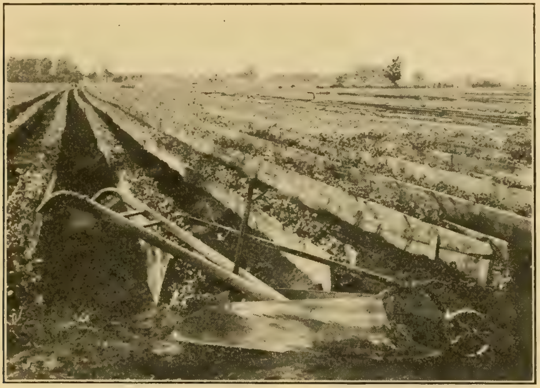

FIG. 13.—A field of celery on much soil showing use of boards in blanching. In foreground a type of celery hiller used in banking celery with soil. (*Courtesy of U. S. Department of Agriculture*).

laid flat along both sides of the row, then two men, working together, at opposite ends of the board take hold of the edge nearest the plants and raise it so that it catches up the leaves. When the board is in a vertical position it is held by one hand while with the other the board on the opposite side of the row is raised. The boards are held in place by wires bent in the form of double hooks 6 to 8 inches long. These wires are placed over the upper edges of the boards at the ends and sometimes at one or two places in between. Short pieces of laths are sometimes tacked across the tops to hold the boards in place. After the boards are in place, a little soil is thrown along the lower edge to close any openings that may be present due to uneveness of the soil, Fig. 13.

Two types of paper are used for blanching celery, ordinary building paper and a paper similar to heavy roofing paper but without the objectionable smell of tar. The latter type is much more durable than the

former and if given the proper care will last for several years. The advantage of the paper over boards lies in the fact that it is much lighter in weight and therefore does not require so much labor to apply. It is more expensive than boards, but when labor of applying is taken into consideration the expense is probably as low as that for boards.

The paper is usually cut into strips 10 to 12 inches wide and is bought in rolls of 100 linear feet. In applying the paper to the celery two rolls are used at a time, one on each side of the row. It is unrolled and set on edge against the celery plants and is held in place by wires bent in the shape of an inverted U, with each leg about 18 inches long. The wires are placed over the row with one leg on each side and the ends are pushed into the soil to the depth of 6 or 8 inches.

Banking with soil is the most economical method. The soil is worked up to the plants gradually in order to avoid getting it into the center of the plant. The banking is usually done by means of a celery hiller, Fig. 13, which pushes the soil against the plants. The wings of the hiller are adjustable so that the soil can be pushed to any desired height. As cold weather approaches the soil is usually worked up to the tops of the plants.

The length of time required for blanching depends upon the variety and the growing conditions. The so-called self-blanching varieties, such as Golden Self-blanching and Easy Blanching, blanch in much less time than the green varieties such as Giant Pascal, Winter Queen, Emperor, etc.

When celery is growing rapidly it will blanch in less time than when growth is slow. In summer 10 days to 2 or 3 weeks are usually required for blanching while in the fall a longer time is required, unless the crop is to be stored, in which case it is not completely blanched when harvested. Green varieties require several weeks to blanch properly but since these are usually grown for late fall and winter use part of the blanching is accomplished in storage. As soon as the crop is properly blanched it should be harvested, because if left too long it loses flavor.

Varieties.[1]—Distinct varieties are not as numerous nor as clearly separable from each other as is the case with most vegetables. Catalogues from sixty leading seedsmen of the United States list only 65 varietal names and it is practically certain that there are not over 20 American varieties that are distinct enough to justify separate naming. Five varieties would include 90 per cent of the commercially grown crop. The most important varieties are Golden Self-blanching, Easy Blanching, White Plume, Giant Pascal, Winter Queen, Boston Market, Emperor, French's Success and Winter King.

Golden Self-blanching is the most important of all celery varieties, representing well over one-half of the total crop. It is understood that

[1] The description of varieties of celery was furnished by Prof. Paul Work of the Vegetable Gardening Department of Cornell University.

this originated as a sport in a green winter variety and it has never been wholly cleared of dark green "rogues." The plant is of medium height, erect, compact in growth, medium early. The foilage is vigorous, but is of a yellowish-green color rather than dark green. The leaf stalk is thin, sharp edged and deeply ribbed. The heart is large, grows up vigorously after blanching has begun and it blanches to a beautiful light golden-yellow color. Its fine appearance makes it an excellent market variety in spite of its rather inferior quality.

Easy Blanching is a relatively new variety. It is not unlike Golden Self-blanching, but is somewhat shorter, less erect, more vigorous and has darker foilage, large heart and is a better keeper. It blanches a little more slowly than Golden Self-blanching. It probably originated near New York City as a sport from Golden Self-blanching.

White Plume is a French sort widely offered by seedsmen, but very little grown as a commercial crop. It is very early, small, spreading in habit of growth. The foliage is a rather pale green. White mottling of the leaves, especially towards the center serves to distinguish it from any other variety. The leaf stalk is slender, thin and distinctly though finely, ribbed. It blanches very white, but is tough and stringy and of inferior quality.

Giant Pascal is the leading late, winter or "green" variety. It is medium in height, strains varying widely in this respect. It is erect and compact in growth. Foliage is vigorous and of a dark green color. The leaf stalk is thick, round-edged and has very shallow, broad ribs, and in many cases it is nearly smooth. This variety is late and blanches slowly to a beautiful creamy-white color. The quality is excellent, even to the outside leaf stalks of well-blanched plants. The heart is rather small compared to the size of the whole plant.

Winter Queen is a late, green celery of little commercial importance. The plant is tall, erect in habit of growth. The leaf stalks are slender, thin and distinctly ribbed. The heart is not heavy and the plant is too tall to be blanched readily.

Emperor is a distinct variety of a somewhat spreading habit with a fairly heavy heart but does not consist of enough stalks to make a good market variety. It is too brittle to stand rough handling. The quality is excellent both as to flavor and texture. The leaf stalks are very short, thick, smooth-ribbed and round. Blanches nearly white.

Columbia represents a type intermediate between Emperor and Giant Pascal.

French's Success and the various other Golden Hearts are winter varieties marked by rather short, thin leaf stalks, distinct ribbing and a heavy heart. They blanch to a light golden-yellow. French's Success is an excellent storage variety as it is a good late keeper, but lacks quality.

Premature Development of Seed Stalk.—Celery growers and other authorities attribute premature development of the seed stalk to various factors including early sowing of the seed, exposure to cold, crowding of plants prior to setting in the field, growing plants in rich soil, growing plants in poor soil, check in growth due to drying, poor seed, and any other factor which checks growth.

Results reported by Whipple (177) seem to indicate that early sowing of seed, use of rich soil and exposing plants to low temperatures (not freezing) for a considerable period in the cold frame favor the premature development of the seed stalk. In 1913 celery started in the greenhouse February 14 produced 30 per cent seed stalks, while the same varieties started March 13 produced a fraction over 1 per cent. In 1914 seed sown February 2 and set in the field June 17 produced 64 per cent seed stalks while those started March 2 and set in the field on June 17 produced only 15 per cent. Plants from seed sown February 1, 1915 produced 70 per cent seed stalks when moved to the cold frame early, while those from March 1 sowing produced 58 per cent seed stalks under the same conditions.

Celery plants grown in extra rich soil in 1913 produced 38 per cent seed stalks while the same stock grown in medium soil produced 18 per cent. Sandy soil gave 30 per cent seed stalks. In 1914 plants grown in soil made rich with well-rotted manure in the case of early planting, produced about 20 per cent more seed stalks than similar plants grown in average greenhouse soil.

In 1914 moving plants to the cold frame early, when their growth was checked by cool temperatures increased the number of seed stalks by 30 per cent. In 1915 plants from seed sown February 1 produced 70 per cent seed stalks when moved to the cold frame early, while plants from the same seeding produced practically none when carried in the greenhouse until time for planting in the field. Plants from seed sown March 2 produced 58 per cent seed stalks when moved to the cold frame early and none when plants were carried in the greenhouse until time for planting in the field. In 1916 plants moved to the cold frame early produced 50 per cent seed stalks, while those kept in the greenhouse produced none As a result of work done in 1918 Whipple reports as follows:

> Seed planted in February with the plants carried in a cool house gave a larger percentage of seed stalks than seed planted one month later. Preliminary tests indicate that short exposure to temperatures from 33 to 40 degrees F. will not cause premature seeding. Where plants are removed to the cold frame early premature seeding is evidently the result of long exposure to low temperatures, which check the growth of plants, and not to short exposure to temperature near the freezing point.

Results of experiments conducted by the author in the gardens of the Department of Vegetable Gardening of Cornell University in 1919, 1920,

1921 and 1922 seem to indicate that early sowing of the seed is at least one of the main causes of celery going to seed prematurely. Checking growth by drying and freezing the plants did not increase the percentage of seed stalks, but on the other hand, apparently delayed their development.

The difference in the relative length of day and night might have a bearing on celery plants from early and late sowing going to seed prematurely, but no evidence is available on the subject.

Pithiness.—Pithiness or "hollow stalk" has been ascribed to check in growth, too rapid growth and to poor seed, especially to seed produced on pithy plants. Sandsten and White (130) and Austin and White (5) have presented evidence to show that pithiness is an inherited character. In 1899 Sandsten and White planted three samples of Golden Self-blanching celery seed, two American grown and one French grown. Two hundred plants of each lot were set in the field and all were given the same attention. At harvest time 40 per cent of the plants from American grown seed were pithy while not a single plant produced from the French grown seed was pithy. In 1901 seeds from five seed firms were secured and 100 plants from each lot were set out. The number of pithy plants in the five lots were 0, 1, 20, 31, 38 and 43. A later setting of plants during the same season produced almost the same results.

Austin and White in 1902 secured similar results to those obtained during the previous years. In 1903, 35 samples of celery seed were tested, and 17 of them produced no pithy plants, 9 produced less than 5 per cent, 4 between 5 and 10 per cent and the remainder produced 15 to 30 per cent pithy plants.

In 1901 a typical Golden Self-blanching stalk that was completely pithy was allowed to go to seed. From this seed twelve plants were raised and every plant was pithy and eleven out of twelve developed into large, coarse, green plants. During the same year seed was saved from a solid stalk and from a pithy stalk of Golden Heart. From the seed of the solid stalk fourteen plants were started and twelve harvested. The twelve were true to type and free from pithiness. From the pithy stalk twenty plants were raised and every one was pithy. These showed a reversion of the type.

As a result of the experiments mentioned the authors conclude that by removing all plants showing any pithiness from the seed plat the difficulty will be obviated.

Diseases.—Celery is susceptible to injury by several diseases including late blight or septoria blight (*Septoria petroselini*), early blight (*Cercospora apii*), bacterial blight, (*Pseudomonas apii*) heart rot . . . . . . , "damping off" (*Rhizoctonia*) and storage rot (*Sclerotinia libertiana*). late blight and early blight are the most common of the field diseases

although bacterial blight is of importance in some regions. All of these can be controlled by thorough spraying with Bordeaux mixture.

Late Blight.—This is the most serious of all the diseases of celery and is found in most regions where the crop is grown. The disease is first observed as brown spots on the leaves, but as it develops these spots may unite causing the entire leaf to become dry. Small black fruiting bodies are usually found on the diseased areas. The fungus lives over winter in the refuse from diseased plants. A considerable portion of the commercial seed also carries the fungus. Some authorities advise disinfecting the seed by soaking in hot water, about 115 to 120 degrees F., for one-half hour. Since the spores are usually dead on 2-year old seed the use of old seed of good germination is also advised. Rotation and sanitation are of value in reducing the injury, but where the disease is present in the soil all of these methods fail to protect the crop. Spraying with 5–5–50 Bordeaux mixture with a soap sticker will keep the disease under complete control if the applications are made at the right time and the work is well done. Spraying to be most effective should begin before the disease appears, but if the spray material is applied as soon as the first spots appear and the plants are kept well covered for the remainder of the season the blight will be controlled. Dusting with copper-lime dust has given good results in various experiments, but the use of this material is still in the experimental stage.

Early Blight.—This disease is widely distributed in the United States. It appears on the plants earlier in the season than the late blight, but seldom does damage until hot weather arrives. It appears on either the upper or lower surface of the leaves as small, yellowish-green spots. The spots enlarge rapidly and in a few days they have a light brown central area gradually turning to dark brown, surrounded by a band of yellow. The disease also attacks the leaf stems, producing long, narrow, water-soaked spots.

Control measures are the same as for late blight.

Bacterial Blight.—This disease has been described by Jagger (77) as follows:

> The spots are of a rusty brown color, irregularly circular in outline and rarely exceed 5 mm. in diameter. They closely resemble the Septoria leaf blight spots and can be distinguished with certainty only by the absence of pycnidia, which show as black dots in the Septoria spots. Occasionally the spots are so numerous as to cause the death of many of the older leaves, but usually the injury consists in the disfiguring of the foliage and in possible reduction in growth of plants. The disease seems to be confined to the leaf blades, spots seldom, if ever occurring on the petioles.

Experiments conducted by Jagger (77) at Irondequoit, N. Y., 1915 and 1917 showed conclusively that thorough spraying with Bordeaux mixture will control this disease.

Harvesting.—Celery may be harvested as soon as it attains the proper size and is well blanched. Early celery is often harvested before the plants are full grown, in order to take advantage of a high price. If

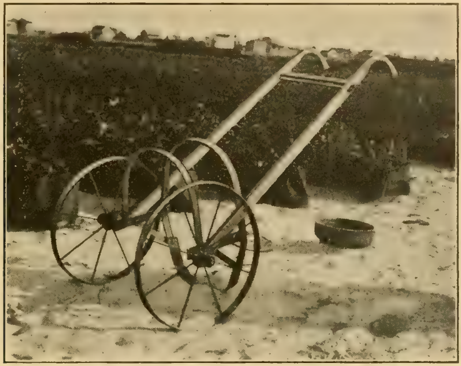

Fig. 14.— A small celery harvester for cutting celery by hand. (*Courtesy af U. S. Department of Agriculture*).

the crop is to be marketed immediately after harvest the stalks should be well blanched, but if it is to be put in storage complete blanching is not desired. During hot weather the celery should be taken from the

Fig. 15.—A field of celery banked with soil and showing a horse-drawn harvester in operation. (*Courtesy of U. S. Department of Agriculture*).

field as soon as possible after it is removed from the row as exposure to sun and wind causes the plants to wilt.

In harvesting the plants are cut off below the surface of the soil, leaving a portion of the roots attached. This may be done with a sharp knife or spade, but where the crop is grown on a large scale special imple-

ments are used. A hand cutter similar to the one shown in Fig. 14 is quite serviceable and is used to a considerable extent. The bean harvester is used to a considerable extent in the celery regions of New York. Various other types are used, many of them being home-made affairs, Fig. 15. With the bean harvester and similar implements two horses are used, one on each side of the row being cut. The cutting bar runs under the row, and is adjustable so that the plant may be cut at any desired depth.

If the crop is to be shipped "in the rough" (without washing and bunching) it is usually stripped in the field and packed into the crates without any further preparation. The filled crates are then hauled direct to the loading station or to market. When it is to be washed and bunched the celery is usually hauled from the field to the wash-house where it is stripped, washed, and put up in bunches and tied.

Most market-garden celery grown for local markets, is washed and bunched on the farm, while a large part of the truck-crop celery is shipped in the rough.

Washing and Bunching.—Before the celery is washed any diseased and badly discolored leaves are removed. It is put into a tank or tub of water and stirred around to remove the loose soil. In some cases a stiff brush is used to remove the dirt, but this usually is not necessary. The stalks are then transferred to another tank or tub for rinsing after which they are bunched. Various sizes and types of bunches are made. In some instances three stalks are tied together, but for shipping twelve stalks to the bunch is most common. In sections of Michigan a round bunch of twelve stalks is put up, while in New York and elsewhere a rectangular bunch is more common. In the latter the bunches are three stalks wide and four deep. The bunches are tied tightly with tape made especially for the purpose, using two ties, one around the butts and one near the upper end of the leaf stalks. After the bunch is tied the hanging or loose foliage is trimmed off with a sharp knife and the bunch plunged into a tub of clean water and is then set on a draining table or board to drain before packing. Where celery is washed on a large scale tanks are arranged in series and water is piped to all of them. Tables, tanks and all other equipment are so arranged that the rough celery comes in at one end where it is stripped, passed along to the wash tanks, then to the bunchers and packers and finally arrives at the opposite end of the room ready for market.

Grading.—Celery, when shipped in the rough is not graded very carefully. In many sections all marketable stalks are put together, while in some instances two grades are made and these are based mainly on size. The Bureau of Markets, U. S. Department of Agriculture, suggests two grades for rough celery, U. S. No. 1 and U. S. No. 2 and the specifications are as follows:

U. S. No. 1 shall consist of well-trimmed stalks of celery of similar varietal characteristics which are not pithy or wilted and which are free from damage caused by seed stems, freezing, disease, insects or mechanical or other means.

In order to allow for variations incident to proper grading and handling not more than 10 per cent, by count, of the stalks in any lot may be below the requirements of this grade but not to exceed one-half of this tolerance shall be allowed for any one defect.

U. S. No. 2 shall consist of stalks of celery which do not meet the requirements of U. S. No. 1.

The following definitions of terms are given:

1. "Well trimmed" means that the outside coarse and damaged branches have been removed and the portion of the root remaining attached to the stalks is not more than 3 inches in length.
2. "Stalk" means an individual plant.
3. "Similar varietal characteristics" means that these stalks in any container have the same color and character of growth. For example celery of Giant Pascal and Golden Self-blanching types must not be mixed.
4. "Pithy" means that the branches have an open texture with air spaces in the central portion.
5. "Free from damage" means that the celery shall not be injured to any extent readily apparent upon examination.
6. "Seed stems" means those stalks which have seed stems showing or in which the formation of seed stems has plainly begun.

Washed celery is graded into two or more grades, the number depending, to some extent, on the demands of the market, and also on the condition of the product. After celery has been in storage for a considerable period and decay has developed three grades are often made; the best grade including large stalks with good foliage. The second grade consists of small stalks or those which require considerable stripping to remove the diseased leaves and the third grade consists of the hearts. When practically all of the foliage has decayed and stalks are stripped down to the heart the commercial term "hearts" is applied to this grade.

Packing.—Celery which is shipped "in the rough" is packed in crates in the field without any preparation except to strip off the damaged and discolored leaves. The crate is usually laid on its side and the celery is placed in it in layers, being packed fairly tightly so that when the crate is full there is no shifting of the product. The celery should not be packed so tightly that air can not circulate through it.

Washed celery is bunched before it is packed in the crate and the bunches are wrapped, or the crate is lined with paper. The paper prevents rapid evaporation from the surface of the celery and protects it from dirt.

Various types and sizes of celery crates are used for packing celery for market. Downing (38) lists 22 well-recognized types of crates commonly used in the United States, while Halligan (58) lists 21 sizes as being employed in Michigan. A few sizes would serve all purposes and a reduction in the number would make for lower cost and eliminate much of the confusion now existing on the market. If a few standard sizes were used it would be possible to give market quotations which would be understood by both the grower and the dealer. The dimensions of the crate with the exception of the depth can be standardized quite easily. The depth should vary in order to accommodate celery of different heights.

Table XXI lists the most important types of crates used in the different celery-growing regions.

TABLE XXI.—TYPES AND SIZES OF CELERY CRATES

Type of container	Inside dimension, in.	Type of container	Inside dimensions, in.
Florida standard	10 × 20 × 22	Texas crate	19 × 22 × 23
Manatee crate	12 × 18 × 22	California 18-inch	18 × 22 × 24
Michigan highball	10 × 12 × 18	California 20-inch	20 × 22 × 24
Michigan special highball	12 × 15½ × 18	California 22-inch	22 × 22 × 24
New York special	20 × 21 × 23	Colorado crate	21 × 22 × 24
New York standard crate	21 × 21 × 23	New Jersey crate (oblong)	18 × 20 × 28
New York crate	22 × 22 × 23	Ohio crate	14 × 18 × 28
New York crate	21 × 22 × 23	Kalamazoo crate	6 × 14 × 21
Oregon 18-inch crate	18 × 22 × 23	Decatur box	6 × 14 × 23
Oregon 20-inch crate	20 × 22 × 23	Grand Haven box	9½ × 9½ × 17
Oregon 22-inch crate	22 × 22 × 23	Hudsonville box	9 × 9 × 17

The Williamson Vegetable Growers Association of Williamson, New York, has adopted a two-thirds crate which is 16 by 22 by 23 inches inside. This crate is much lighter, more convenient to handle and keeps the celery in better condition than the standard crate.

Storage.—To keep celery successfully for any considerable period it must be free from disease and other injury at time of storage, and kept at a low temperature, but not allowed to freeze. Various methods of storage are in use including (1) trenching in the field; (2) storing in pits; (3) storing in specially constructed storage houses and (4) storing in cold-storage houses.

1. Trenching in the field is practiced where the celery is to be held for a relatively short period in the fall. By this method eight to ten

rows of celery are brought together and set with the stalks close together in a shallow trench. The trench is often opened with a plow by running two or more times in the row and then shoveling out the loose soil in the bottom. When the trenching is done to protect the celery against freezing for a short period soil is thrown over the plants with a plow. For longer storage, 2 months or more, boards are often set along the sides of the trenches and the celery is placed between them. Soil is then banked up along the sides of the trench and a covering of boards is put on. Often a layer of straw, hay or other material is placed on the boards and over this a thin layer of soil to prevent the material from being blown away. As the weather gets cold more soil is added to protect the celery against freezing. Another method of covering the trench is to nail boards together in the form of a V and invert them over the trenched celery. The boards are banked with soil or manure when necessary to prevent freezing.

Any type of trench storage is objectionable because the temperature and moisture cannot be controlled. If a period of wet weather sets in and this is followed by several warm days the celery may rot in two or three weeks.

2. Storing in pits is practiced by market gardeners in many regions, especially in the vicinity of Boston. Blanching boards are often used for the roof of these pits and when the boards are 12 feet long the width of the pit is usually 22 to 23 feet. The roof is 7 to 8 feet high at the ridge and 3 to 4 feet high at the eaves. It is supported by one line of posts through the center and two lines half way between the ridge and eaves. The ridge is made of 2 by 6-inch planks, while the purlins may be of the same material, or 2 by 4-inch pieces. The sides of the pit may be of earth, or of planks with soil banked against the outside. The roof is covered with leaves, hay or other material and soil may be placed over this covering.

The celery is set in rows 3 to 4 inches apart and the plants touching in the row. Soil is firmed around the roots to hold the plants in position. Sound celery can be kept in these pits until spring, if proper attention is given to ventilation and temperature. A temperature of 32 degrees F. is considered the best. With a temperature much higher the storage season will be shortened and at a temperature below this there is danger of serious freezing. The green varieties of celery will usually keep for a longer period than the self-blanching varieties.

3. Storing in specially constructed houses, built partly below ground, is not practiced to the extent that it was formerly. These houses are similar to those built for storing root crops. The celery is placed in the houses in much the same way as in the pits described above. The main advantage of the house over the pit is that the former is a permanent structure while the latter must be made every year.

4. Cold storage of celery is comparatively new, but at the present time it is the most popular method of storage. A large part of the late truck-crop celery, grown in the North is stored in cold-storage warehouses for 6 weeks to 3 months or more. In addition to this a considerable portion of the California and Florida celery is stored for short periods.

Cold storage has many advantages over the other methods, especially in the control of temperature and humidity. It is impossible to control either in the trench method of storage, and even in the pit and common storage house, it is not possible to keep the temperature down during a period of warm weather in the fall. It requires less labor to store celery in cold-storage warehouses than in the other types of structure. It is packed in crates in the field and is not disturbed until it reaches the market. This method of storage is the most convenient as the warehouses are equipped with elevators, trucks, etc. for handling the celery and they are usually located on a railroad siding so that the product can be loaded for shipment in any kind of weather. This is not true of the other types of storage. In fact, in field storage it is unsafe to remove celery when the temperature is very low on account of danger of freezing and it is very disagreeable work under such conditions.

Most authorities recommend a temperature of 32 degrees F. for the celery storage room and it is the aim of the managers of most cold-storage houses to maintain this temperature. This is probably safe since there is considerable variation in temperature in different parts of the room due to lack of air circulation. It should be borne in mind, however, that when the air temperature is at 32 degrees F. the celery in the center of the crate is much higher and also that celery does not freeze at the freezing point of water. In experiments conducted by the author (159) the temperature of the celery averaged 4.1 degrees F. higher than the air at the same height in the storage room. In no instance did the celery freeze, even the outside stalks, unless the temperature remained below 30 degrees F. for several hours. When freezing occurred it was in the bottom crates where the temperature was two or more degrees lower than at the height where thermometers are usually located in the storage rooms. Where the thermographs registered a temperature of 28 degrees F. near the floor there was always some freezing of the outside stalks in the bottom crates, but none in crates above the bottom tier.

The type and size of crates used in storing celery has an effect on the keeping of the product in storage. Table XXII gives the results of experiments carried on for 4 years 1912–1913 to 1915–1916 in cold-storage houses in New York State (159). Each year five crates of each type were filled with celery and stored under identical conditions.

TABLE XXII.—KEEPING QUALITY OF CELERY AS INDICATED BY THE AVERAGE PERCENTAGE OF DIFFERENT GRADES FOUND AT THE END OF THE STORAGE PERIOD

Type of crate	Grades, per cent			
	Sound	Slightly decayed	Badly decayed	Worthless
Standard	46.25	42.88	9.0	1.8
Partition	73.10	23.12	2.9	0.73
16-inch (for three years only)	74.14	22.10	3.18	0.58
14-inch (for three years only)	78.88	18.00	2.28	0.70

Examination of Table XXII will show that the percentage of sound celery was highest in the small crates and lowest in the standard crate. The larger amount of decay on the celery in the standard crate was undoubtedly due to a higher temperature in the standard crate than in the others. In 1914–1915 the average temperature of the celery in the center of the standard crate at the height of the third tier, was 36.2 degrees F. for the entire storage period of three and one-half months, and in the partition crate at the same height 34.2 degrees F.

The effect of temperature on the keeping quality is also indicated by the difference in the percentage of different grades of celery stored at different heights in the storage house. (See Table XXIII.)

TABLE XXIII.—KEEPING QUALITY OF CELERY AS INDICATED BY THE AVERAGE PERCENTAGE OF STALKS OF DIFFERENT GRADES FOUND AT DIFFERENT HEIGHTS IN THE STORAGE ROOM WHEN STORED IN STANDARD CRATES

Tier	Sound	Grades, per cent		
		Slightly decayed	Badly decayed	Worthless
First (bottom)	64.9	30.0	2.6	2.6 (frost)
Second	56.7	34.6	7.2	1.3
Third	50.0	43.2	6.2	0.6
Fourth	38.9	53.7	6.2	1.2
Fifth (top)	6.2	63.0	29.0	1.2

The small amount of sound celery in the top tier was due in part to the effect of the drip from the refrigerator pipes in one of the storage rooms, but the difference in keeping quality of celery in the other tiers was undoubtedly due to the temperature factor. The difference in temperature of the celery in the standard crates and of the air is shown in Table XXIV.

Table XXIV.—Temperature of Celery in the Standard Crate and of the Air in a Celery Storage Room

Tier	Temperature, degrees Fahrenheit	
	Of celery	Of air
First (bottom)	33.9	31.6
Third	35.8	32.8
Fifth (top)	36.6	33.8

A glance at the above table shows that the temperature in the center of the crate averaged from 2.3 to 3 degrees higher than the air, on the outside of the crate, throughout the storage period. This indicates that celery is very active. During the first part of the storage period normal ripening processes are going on and after this is completed there is a breaking down of the cells and this is followed by decay, due mainly to soft rot. In both the ripening and breaking down processes heat is liberated. Just before the breaking down process begins there is a period when the temperatures in the crate and on the outside are nearer together than at any other time. The more rapid the ripening and decay processes the greater the difference between the celery and air temperature.

LETTUCE

Lettuce is the most popular of the salad crops, being grown in nearly all home gardens, in cities as well as on farms. In commercial value it ranked in 1919 next to celery, while in acreage it was the leading salad crop grown in the United States. The increase in commercial acreage and value of lettuce from 1909 to 1919 was greater than that for celery. According to the Bureau of Census there were 5,489 acres of lettuce valued at $1,595,085 in 1909 while in 1919 the acreage was 21,544 and the value $8,535,092. The acreage was nearly four times as large in 1919 as in 1909 and the value of the 1919 crop was more than five times that of the 1909 crop. Nearly two-thirds of the lettuce grown in the United States in 1919 was produced in four states. California with 6,121 acres was in the lead, followed by New York with 3,392 acres, Florida 2,664 and New Jersey with 1,123 acres.

Lettuce thrives best in a fairly cool growing season and hence is grown in the South during the fall, winter and early spring. In the North it is grown mainly in early summer and in the fall, since it is very difficult to produce a good crop of the commercial varieties during the hottest part of the summer. In California it is grown mainly in the fall and winter, but along the coast it can be grown all the year. It does not head well during hot weather and often goes to seed prematurely under unfavorable conditions.

History and Taxonomy.—Lettuce is probably a native of Europe and Asia and has been in cultivation at least 2,500 years. It is mentioned frequently by ancient writers, some as far back as 500 B. C.

Cultivated lettuce *Lactuca sativa* is related to the wild lettuce *L. scariola*, a common weed in the United States. The two cross readily and are considered by some botanists as belonging to the same species. Lettuce is an annual and belongs to the Compositae or sunflower family.

There are three distinct types of lettuce grown in the United States; namely head, cutting or leaf, and cos. There is a fourth type, called asparagus lettuce, little known in this country, but resembling the cos type. This does not form a compact head, but is grown for its thick stem. These four types are recognized as botanical varieties or subspecies and are known under the following names: Head lettuce, var. *capitata;* cutting or leaf lettuce var. *crispa;* cos or romaine var. *longifolia;* asparagus lettuce var. *angustana.*

Soil Preferences.—Lettuce is grown on practically all types of soil, but the crop is produced commercially mainly on sandy loams, silt loams and mucks. Sandy loams are preferred to other types for a very early crop in the North, and for the winter crop in the South. A good muck soil is considered almost ideal for lettuce because of the high water-holding capacity and the ease with which this soil is worked. A large part of the lettuce produced during the summer in New York and Michigan is grown on muck.

The soil for lettuce should be deep and well drained, but retentive of moisture since the lettuce plant has a small root system and is therefore a poor forager. The soil should be thoroughly prepared before the crop is planted as most of the cultivation is done by hand, and hand tools cannot be used to good advantage on rough, poorly-prepared soil. After plowing, disking and harrowing with the ordinary implements it is desirable to use a meeker harrow on upland soils and a drag or light roller on muck soils. Either the meeker harrow, or the drag will make a smooth surface and leave the soil in good condition for seed sowing.

Manures and Fertilizers.—Where lettuce is grown on upland soils in the North manure is usually used in large quantities and this is considered necessary in order to keep the soil in good physical condition. Large quantities of manure are not necessary if the humus is supplied in green-manure crops and the nutrients in commercial fertilizers. Results of 6 years experimental work on a Miami silt loam soil at the Rhode Island Experiment Station (66) show that 16 tons of manure supplemented with 1,500 pounds of a 4–10–2 fertilizer produced larger crops than 32 tons of manure alone. The average yearly yield of marketable lettuce was 16,500 pounds per acre where 32 tons of manure were applied, 19,000 pounds on the plats having an application of 16 tons of manure and 1,500 pounds of a 4–10–2 fertilizer. Where more nitrogen was

added to the fertilizer no increase in yield was secured but extra phosphorus increased the yield 900 pounds to the acre. Extra potash resulted in a decrease in yield.

The percentage of No. 1 heads was much higher on the plats treated with 16 tons of manure and the commercial fertilizer than on those treated with 32 tons of manure, with the exception of the plats receiving additional potash. On this plat the total yield was less than on the other and the percentage of No. 1 lettuce was much lower. There is considerable evidence that heavy application of potash salts increases "tip-burn" and this may have been a factor in decreasing both the yield and the percentage of No. 1 heads in these experiments, although it is not mentioned by Hartwell and Crandall (66). In fact they make no explanation of the low yields on the plats given additional potash. (See Table IV for data.)

On mineral soils the humus content must be maintained and if manure is not used, green-manure crops should be turned under. In addition to the green-manure crops an application of 1,000 to 2,000 pounds of high-grade fertilizer should be used. A fertilizer containing 4 to 6 per cent ammonia, 6 to 8 per cent phosphoric acid and 4 to 8 per cent potash will give good results if the soil and weather conditions are favorable for lettuce growing.

On muck soils a fertilizer containing 2 to 4 per cent ammonia, 8 per cent phosphoric acid and 4 to 8 per cent potash is used. Applications of 1,500 to 2,000 pounds to the acre are commonly made. In view of the evidence concerning the effects of potash salts on "tip-burn" it is inadvisable to use more than 4 per cent potash where 1,500 pounds or more of the mixture is applied to the acre.

Broadcasting the fertilizer before the crop is planted is the most common method of applying. Additional applications of nitrate of soda are often made while the crop is growing, using 100 to 200 pounds to the acre at each application. Usually not more than two applications are made.

Growing Plants for Transplanting.—For a very early crop of lettuce the seed is sown in a greenhouse or hotbed several weeks before time for setting in the field. If they are to be taken direct from the seed bed to the field 5 to 6 weeks is sufficient time to allow between seed sowing and outdoor planting. This method is not satisfactory and the more common practice is to sow the seed 8 to 10 weeks before the date for field setting and to transplant the young plants when they are about 3 weeks old. The plants are spaced 1½ by 1½ or 2 by 2 inches apart either direct to the soil of the greenhouse, hotbed, or cold frame, or preferably into flats. They should be hardened before being set in the field and this is often done by moving them into a cold frame and exposing them gradually to lower temperatures.

Planting in the Field.—Hardened plants and seeds may be planted as soon as hard freezes are over. In many sections of the North seed is sown at intervals throughout the spring and summer while in the South plantings are made from late summer through the fall and winter. In the interior valleys of California the first planting is usually during the latter part of August and other plantings are made in October and January or February. Along the coast, where the climate is moderate the crop may be planted any time during the year. In most sections of the United States head lettuce cannot be grown successfully during the hottest part of the average summer. Even in New York and Michigan it is seldom that a first-class crop is produced in August, although an occasional good crop is secured at that time.

Where the seed is sown direct, a hand seed drill is usually used and 2 to 3 pounds are sown to the acre with the rows spaced 12 to 15 inches apart. With wider spacing for horse cultivation less seed is required. The plants are thinned to stand 8 to 12 inches apart, the distance depending upon the variety, and, to some extent, upon the richness of the soil. As soon as the plants are well established they are usually "blocked out" with a hoe and later the clump is thinned to a single plant. The thinning should not be delayed or crowding will produce weak spindling plants. In some sections where lettuce is grown on muck soil, the plants removed in thinning are transplanted to other beds, but it is doubtful if this is a good practice. The plants which are left usually produce a better crop than those transplanted and the latter operation is probably more expensive than thinning.

Where plants are set out the rows are spaced the same distance apart as for seed sown direct to the field. In the rows they are given about the same space as the thinned plants. The plants are set by hand, the method depending upon the kind of soil and the character of the plants. If the plants have been transplanted prior to going to the field a trowel is often used, or a small shallow furrow may be made with the plow attachment of the hand cultivator. On muck soils the hole for the plant is usually made by hand since the soil is very light.

When the soil is dry, watering is necessary either before or after setting the plants. This is especially important when they are taken from the seed bed, since no soil adheres to the roots of the plants.

Cultivation.—Frequent, shallow cultivation is important for lettuce as the plants cannot compete successfully with weeds. The root system of lettuce plants is very small and many of the roots are near the surface; therefore maintaining a soil mulch by shallow cultivation is important for water conservation. When weeds are troublesome the knife attachments of hand cultivators, or scuffle hoes are better than the cultivator teeth. The knives and scuffle hoes cut off the weeds below the surface and leave a thin layer of mulch, without injuring the lettuce

roots. When the surface soil is loose and no weeds are present nothing is gained by continuing cultivation. On the other hand, cultivation under these conditions may be injurious by bringing moist soil from below, to the surface where it will dry out, and, also by breaking the roots. There is a tendncy to deepen cultivation as the surface becomes dry, due probably to the desire to see moist soil. Of course, this is a mistake for all soil brought to the surface dries out if the weather remains dry. In fact this is the method used in the spring to hasten the drying of the soil.

Hand weeding between the plants in the row is usually necessary and this is a tedious and expensive operation. On muck soil this is usually done with the hands as the soil is light, but on upland soils hoes are often used for a part of the work. Loosening the soil by hoeing is an advantage since a mulch is formed between the plants.

Varieties.—The great popularity of lettuce and the varied conditions under which the crop is grown are probably responsible for the large number of varieties and the still greater number of varietal names. Tracy (166) in his classification of lettuce recognized over one hundred distinct varieties. Lester L. Morse (97) of the C. C. Morse and Company, San Francisco, California, one of the largest lettuce seed growers, states that twenty varieties cover practically all of those grown in America. Lettuce varieties have been classified by various authorities, the most complete classification being that worked out by Tracy (166) which is as follows:

Class I. Butter varieties.
- Subclass 1. Cabbage-heading varieties.
  - Color Divis on I. Plants wholly green. Philadelphia Butter, Black Seeded Tennis Ball, etc.
  - Color Division II. Plants tinged brownish, larger part green. California Cream Butter, Big Boston, White Seeded Tennis Ball, etc.
  - Color Division III. Plants brownish, small portion only greenish. Brown Head Eureka, Sugar Loaf.
- Subclass II. Bunching varieties.
  - Color Division I. Plants wholly green. Oak-leaved, Earliest Cutting, Golden Heart, Lancaster.
  - Color Division II. Plants brownish.

Class II. Crisp varieties.
- Subclass I. Cabbage-heading varieties.
  - Color Division I. Plants wholly green. Brittle Ice, Hanson, New York.
  - Color Division II. Plants tinged with brownish, large part greenish. Density, Iceberg, Marblehead, Mammoth.
  - Color Division III. Plants brownish, small part only greenish. Chartier, Mignonette, Sugar Loaf.
- Subclass II. Bunching varieties.
  - Color Division I. Plants wholly green. Black-seeded Simpson, Boston Curled, Grand Rapids, White-seeded Simpson.
  - Color Division II. Plants brownish, small part only greenish. American Gathering, Chartier, Prize Head.

Class III. Cos varieties.
  Subclass I. Spatulate-leaved varieties.
    Heading Division I. Self-closing.
      Color Division I. Plants wholly green. Dwarf White Cos, Express Cos, Giant White Cos, Green Cos, Paris White Cos, Prince of Wales Cos.
      Color Division II. Plants brownish. Red Winter Cos.
    Heading Division II. Loose-closing. Bath Cos.
  Subclass II. Lanceolate-leaved varieties. Asparagus.
  Subclass III. Lobed-leaved varieties. Asparagus Lobed-leaved.

Of the butter varieties the most important are Big Boston (Fig. 16), California Cream Butter, Tennis Ball, both white-seeded and black-seeded, Deacon, Wayahead and Salamander. The Big Boston is grown

FIG. 16.—A good head of Big Boston lettuce, the best known of the butter varieties. (*Courtesy, C. C. Morse & Co.*)

commercially to a greater extent than all other varieties of this group. California Cream Butter and Wayahead withstand heat better than the Big Boston and do not go to seed as quickly.

Among the crisp varieties of head lettuce the Hanson, Los Angeles, Iceberg, New York (Fig. 17) (Wonderful or New York Wonderful), Crisp as Ice and Mignonette are among the best known. Hanson is grown mostly for home use and for local markets. Los Angeles is the most popular shipping variety grown in California. It develops a large, solid head, matures quickly and has a good flavor. It withstands cold without injury, but does not thrive well in hot weather as it quickly

goes to seed under high temperatures. Iceberg is grown extensively in California and other sections of the West, and to some extent in the East. This variety is one of the best of the large heading varieties to grow in hot weather. It is similar to the Los Angeles. Mignonette is one of the smallest, if not the smallest heading variety. It is excellent in quality, but is not important as a commercial variety because of its small size, reddish brown color and its habit of going to seed quickly. New York is similar to Iceberg in appearance and quality. It withstands hot

FIG. 17.—An ideal head of lettuce of the crisp class. (*Courtesy, C. C. Morse & Co.*)

weather well. Among the crisp varieties are found the best sorts to plant for maturity during very hot weather since none of the butter varieties will withstand as much heat as Iceberg and New York. However, the crisp varieties are not so popular on many markets as the butter varieties and for this reason Big Boston and others of this type are grown even under conditions unfavorable for its best development.

Among the leaf varieties, Grand Rapids (Fig. 18) Prize Head, early Curled or White-seeded Simpson and Black-seeded Simpson are the most popular. These are not grown to any great extent in the field, although they are very popular in the home garden. For growing in greenhouses during the winter these varieties are used almost exclusively except in sections of the East as in the vicinity of Boston and Rochester.

White Paris Cos (Fig. 19), (White Cos, Paris White Cos) is the most important variety in the cos class, although Express Cos and Giant White

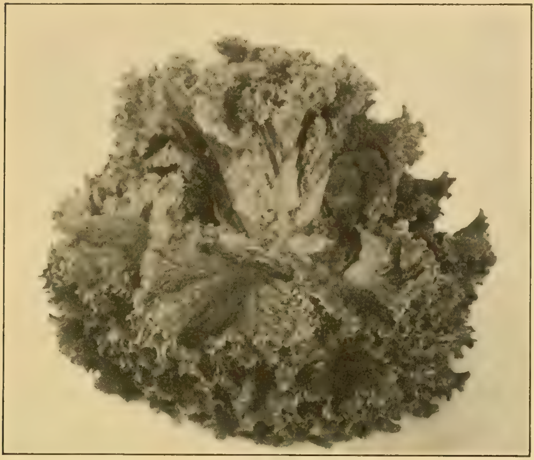

Fig. 18.—Full-grown plant of Grand Rapids lettuce, one of the best representatives of the bunching varieties. (*Courtesy, C. C. Morse & Co.*)

Fig. 19.—Cos lettuce showing the general character of the head and the shape of the leaves. (*Courtesy, C. C. Morse & Co.*)

Cos are grown to some extent. Cos lettuce is becoming more popular each succeeding year and is being grown at the present time on quite a large scale in various sections of the United States. Considerable acreages are grown on the muck soils in New York and other states.

Diseases.—Lettuce is affected by a number of diseases including bottom rot (*Rhizoctonia solani*), drop (*Sclerotinia libertiana* and S. *Minor*), gray mold or Botrytis rot (*Botrytis cinerea*) anthracnose (*Marssonia panattoniana*) mildew (*Bremia lactucæ*), tip-burn and mosaic. Fortunately these diseases, when present, are not always serious, although under favorable conditions any one may greatly injure or even practically destroy the crop.

Bottom Rot.—This disease may effect the plants in any stage of development, frequently causing damping-off of the seedlings. On plants of considerable size the disease shows as rusty, slightly sunken areas on the leaf stalks where they come in contact with the soil and sometimes the total rotting of the leaves. The entire head may rot and remain as a blackened stump. No means of control are known that are practicable in the field. In the greenhouse, soil sterilization will prevent the development of the disease. Thorough drainage and frequent cultivation to dry the surface soil will reduce, to some extent, the development of bottom rot.

The more upright types of lettuce are less affected and some progress has been made in developing a type with the heading characteristics of the Big Boston and the erect habit of growth of the cos. Crosses made by Dr. H. W. Dye of the Department of Plant Pathology, Cornell University are promising, although the work is in the early experimental stage.

Drop.—Plants affected by this disease become water-soaked and collapse with a soft rot in a few hours. The rotting of the plants first attracts attention. On the under side of the lower leaves will be seen a white fungus and later there appear nodules which become black. These black bodies can be found in any of the decayed parts of the plants. This disease is widespread and often causes large losses, sometimes whole fields of lettuce being destroyed. The organism also attacks other plants. No very satisfactory control measures for field lettuce are known, although prompt removal of affected plants and drenching the soil with a solution of copper sulphate is reported to be of value. This, however, is not a very practicable method of treating large areas. In the greenhouse, soil sterilization is practiced to control this and other diseases.

Gray Mold.—This disease is seldom serious in the field, but is an important disease of greenhouse lettuce. It first appears on one leaf or on one side of a plant, but it may spread and destroy the entire plant. A gray fungus growth occurs on the rotted tissues. In the greenhouse care in watering and ventilating will usually keep this disease in check.

Anthracnose.—Plants affected by this disease first show lesions on the leaves. These lesions appear as roundish water-soaked spots which become brown. Later the affected tissues drop out, giving the leaf a shot-holed appearance. On the midrib the spots are sunken and irregular in outline. Rotation of crops is recommended for this disease in the field. In the greenhouse, sanitation and maintaining a relatively high temperature will aid in controlling the anthracnose.

Mildew.—This is primarily a disease of greenhouse lettuce and can be kept in check by proper control of watering, ventilating and heating.

Tip-burn.—This disease is apparently not due to any parasitic organism but to unfavorable conditions. Blackening of the margins of the leaves is characteristic of this disease and this may be found on the inner leaves. Tip-burn is often very serious when lettuce matures in very hot weather and is seldom of much importance during cool weather of fall. There is evidence that an excess of potash (and possibly nitrogen) may increase the development of tip-burn. No control measures have been found.

Mosaic.—Jagger (78) has reported on a mosaic disease of lettuce which is very serious in Florida and in South Carolina. Probably the same disease is present in New York and other states since mosaic is common some years in the lettuce-growing sections. Jagger has shown that this disease is transmitted by a species of aphis, and since no organism has been found the method of control would seem to be to protect the plants from the insects. Spraying with some of the tobacco sprays or dusting with nicotine dust would probably be of value.

Insects.—The most important insect pests of lettuce are various species of plant lice or aphis. Control measures for these are the same as for the spinach aphis. The cabbage looper also attacks lettuce. For description of this insect and control measures suggested see under cabbage. Cutworms sometimes injure lettuce early in the season and may be controlled by poison mash as recommended in Chapter XIII.

Harvesting.—The stage of development at which lettuce is harvested depends upon the type and the purpose for which it is grown. Head lettuce, when grown for market, is allowed to grow to full size and to develop a solid head. When grown for home use it is often harvested before the head is well formed, but when used as leaves there is no advantage in growing a heading type. Leaf lettuce grown for home use is harvested at any time after the plants get large enough for use. A common practice is to thin the plants at various times, removing the largest ones for use and leaving the small ones to develop. In this way one planting will supply the table for a considerable period. When grown for market leaf lettuce is usually allowed to develop to full size, unless the price is very high prior to that time, in which case the plants are cut any time after they become half-grown. Of course, a larger yield

will be produced on a given area if the plants are allowed to develop to full size than if cut earlier, but the returns may be as high under the latter practice.

Lettuce is usually harvested by hand, using a long sharp knife to cut the plant just above the surface of the ground. Better results are secured, however, if the plant is cut above the lower leaves or those which are in contact with the soil. This is especially true if the crop is affected with lettuce drop. Ramsey and Markell (120) have shown that by careful cutting and removing the bottom leaves of lettuce grown in fields where "drop" is serious, it arrives on the market in much better condition than lettuce cut in the ordinary manner. During the winter of 1913–1914 experiments were conducted in Florida to determine the effects of different methods of handling on the quality of the product when it reached the market. Some of the lettuce was carefully cut so as to remove the diseased leaves while comparable lots were cut in the ordinary way. Nine lots were shipped to New York and were examined on arrival and 3 days later. The results are given in Table XXV.

Table XXV.—Average Market Condition of Nine Experimental Lots of Carefully Cut and Commercially Cut Lettuce Shipped to Northern Markets During the Season of 1913–1914

Treatment	At withdrawal		Three days after withdrawal	
	Carefully cut	Commercially cut	Carefully cut	Commercially cut
Non-precooled:				
Prime heads, per cent	59.6	25.7	46.4	17.3
Marketable[1] heads, per cent	100.0	96.5	99.2	91.8
Precooled:				
Prime heads, per cent	71.5	33.7	58.0	22.8
Marketable heads, per cent	100.0	99.6	100.0	98.4

[1] The term "marketable" as used here includes all heads with sound hearts, even though the outer leaves were in some cases more or less decayed.

Table XXVI shows the percentage of heads affected with drop rot in different stages of development at the time the lettuce was withdrawn from the car and after it was held in the commission house for three days.

In addition to the factors recorded, the difference in appearance of the various lots was a point of great importance. In almost every case the carefully cut lots were far more attractive, not only because less decayed but also because the heads were cleaner owing to the removal of the dirty lower leaves.

TABLE XXVI.—AVERAGE PERCENTAGES OF DECAY IN NINE EXPERIMENTAL LOTS OF CAREFULLY CUT AND COMMERCIALLY CUT LETTUCE SHIPPED TO NORTHERN MARKETS DURING THE SEASON OF 1913–1914[1]

Treatment	At withdrawal		Three days after withdrawal	
	Carefully cut	Commercially cut	Carefully cut	Commercially cut
Non-precooled:				
Heads showing slight drop rot	7.9	24.2	11.7	30.3
Heads showing medium drop rot	0.9	16.9	3.3	19.6
Heads showing complete drop rot	0.0	3.4	0.3	5.9
Total drop rot	8.8	44.5	15.3	55.8
Precooled:				
Heads showing slight drop rot	4.7	20.6	8.5	26.8
Heads showing medium drop rot	0.4	6.3	1.4	8.3
Heads showing complete drop rot	0.0	0.3	0.0	1.6
Total drop rot	5.1	27.2	9.9	36.7

[1] No record of bacterial decay was obtained in these lots.

In addition to the experimental shipping lots, 16 lots were held in a refrigerator car at Palmetto, Florida. These were inspected in the same way and at about the same time as those shipped to New York. The difference between the carefully cut and commercially cut lots were even more striking than in the lots shipped. The effect on the carrying quality of lettuce of the different methods of handling employed was relatively the same in both lots.

Grading.—Lettuce is not carefully graded under most conditions. Head lettuce in particular, should be graded into at least two grades, the first including the large solid heads and the second grade including those heads which do not meet the requirements for the best grade but are still marketable. The U. S. Bureau of Markets has suggested three grades, U. S. Fancy, U. S. No. 1, and U. S. No. 2. The specifications for these are as follows:

U. S. Fancy shall consist of sound heads of lettuce of similar varietal characteristics which are fresh, neatly trimmed and firm; which are not wilted, decayed, burst, or showing seed stems or doubles and which are free from damage caused by freezing, tip-burn, disease, insects or mechanical or other means.

Each head of lettuce shall weigh not less than 1 pound.

In order to allow for variations incident to commercial grading and handling 5 per cent, by weight, of any lot may be below the prescribed minimum weight and, in addition 4 per cent, by weight, of any lot may be below the remaining requirements of this grade.

U. S. No. 1 shall consist of sound heads of lettuce of similar varietal characteristics which are fresh, partially trimmed and reasonably firm; which are not wilted, decayed, burst, or showing seed stems or doubles and which are practically free from damage caused by freezing, tip-burn, disease, insects or mechanical or other means.

Each head of lettuce shall weigh not less than ¾ pound.

In order to allow for variations incident to commercial grading and handling 5 per cent, by weight, of any lot may be below the prescribed minimum weight and, in addition 7 per cent, by weight, may be below the remaining requirements of this grade.

U. S. No. 2 shall consist of heads of lettuce which do not meet the requirements of U. S. No. 1.

Packing.—Before packing lettuce it should be trimmed to remove diseased and dirty leaves, and separated into grades, in case any separation is made. In some sections the packing is done mostly in the field and in others the lettuce is hauled to a packing shed where it is trimmed and packed. In packing head lettuce in crates or boxes the bottom layer is placed with the stem end down and the others reversed, thus protecting the heads in transit. When baskets and hampers are used the same method of packing may be used, or all of the heads with the exception of the top layer may be placed with the stem end down. The top layer is always placed with the stem end up. In some regions when lettuce is graded into two grades, the better grade is often packed in crates and the second grade in one-bushel hampers.

Lettuce is marketed in about thirty styles of boxes and crates and in various types and sizes of baskets, hampers and barrels. For head lettuce crates are much better than baskets as they are much more attractive and show off the product to better advantage. Among the more popular crates are the New York type which holds 2 dozen heads and is made in sizes, 7½ by 16 by 20 inches, 8 by 16 by 20 and 7½ by 16½ by 19 and the California crates holding 3 to 5 dozen heads made in five sizes, 13 by 19 by 22⅛, 12 by 18 by 22⅛, 13 by 17 by 22⅛, 10 by 13½ by 18 and 13 by 18 by 21½. Downing gives the dimensions and capacity of 20 different types of crates and makes the following comment on them:

A study of the dimensions of those crates shows that many are similar in size. There appears to be a very strong demand for a crate holding 2 dozen heads of lettuce. The dimensions of the 2-dozen crate could certainly be readily standardized. There is also a considerable call for a lettuce crate holding from three to five dozen heads. The California standard crate with the inside dimensions 13 by 18 by 22⅛ inches is suggested as a possible standard crate in the larger size.

Storage.—Lettuce is not usually considered a storage product, but under good refrigeration it can be kept for a period of 3 to 4 weeks provided it arrives at the storage house in good condition. For storage it is packed as for market and is placed in cold storage where the temperature is kept at about 32 degrees F. Storage is of great importance since it often happens that the market is glutted for a few weeks and then is nearly bare for a period. Storage prevents this glut and tides the market over the period of slack production. This helps both the producer and the consumer.

In some sections lettuce is hauled direct from the field to the storage house, where it is precooled before it is loaded into cars. This may be a good practice, but the same results can be secured in a properly-constructed refrigerator car. Well-constructed cars with basket bunkers and false floors, give good refrigeration and rapid cooling, especially if salt is used with the ice at the first icing. Precooling by placing in cold storage, is not important, if the lettuce can be loaded direct into cooled cars equipped with basket bunkers and false floors. In fact it is probable that the cooling is as rapid in the type of car mentioned as in the average cold storage room where there is no forced circulation of air.

ENDIVE

Endive (*Cichorium Endivia* Linn.) belongs to the Compositae or sunflower family and is probably of East Indian origin. It was used as food by the Egyptians at a very early period, being referred to by Pliny, who states that it was eaten as a salad and potherb in his day. As now grown endive is eaten mainly as salad, taking the place of lettuce. It is grown mainly by market gardeners near large cities, where it is consumed largely by the foreign population.

Culture.—The general methods of culture of endive are practically the same as for lettuce. It is grown mainly for fall and early winter markets, although it can be produced as an early summer crop by starting the plants under glass, or even by sowing the seed in the open very early in the spring. For the fall crop in the North the seed is sown in July or August. In the South it can be grown as a winter crop. If planted in the spring in the North the seed may be sown as soon as hard freezes are over since the crop will withstand light freezes. The plants make the most satisfactory growth during cool weather.

The distance of planting is about the same as for lettuce, the rows being 15 to 18 inches apart for hand cultivation, with the plants thinned to stand 6 to 10 inches apart in the row.

Any soil suitable to lettuce culture is satisfactory for endive. Rapid growth is important, as for all other salad crops, in order to procure

tender, crisp leaves. The same soil treatment recommended for lettuce is suggested for this crop.

Blanching.—When the crop is grown for salad the leaves should be thoroughly blanched to reduce the bitterness and to render them more tender. Blanching also improves the appearance of the leaves when they are to be used for garnishing.

Blanching requires 2 to 3 weeks, or even longer in cool weather. Any method which excludes the light from the central leaves and keeps them dry is satisfactory. The most common method is to gather all of the leaves into a bunch and tie them near the top. If rains or cloudy weather follow the tying it is important to examine the crowns frequently to see that they are not decaying. After the inner leaves are blanched they should be harvested quickly to prevent decay. Covering the plants with boards, hay, straw or other material is sometimes practiced. When grown in the greenhouse great care must be taken to keep the house cool and the atmosphere relatively dry during blanching. Paper covered frames have been recommended for blanching endive by S. N. Green (Mo. *Bull.* 32, Ohio Exp. Sta.). These frames exclude the light and allow a fair circulation of air.

Varieties.—There are two types of endive, the curled or fringed-leaved and the broad-leaved varieties. The former is more ornamental and much more largely grown than the latter in the United States. The most popular varieties of the curled type are Giant Fringed, Green Curled Winter and White Curled. Broad-leaved Batavian is the best known of the broad-leaved type and this is used mainly in stews and soups and as a potherb.

CHICORY

Chicory (*Cichorium intybus* Linn.) also known as French endive, Witloof, Witloof chicory and succory, is probably a native of Europe and Asia. It has been in use as a salad plant from time immemorial, but was probably not cultivated by the Ancients. It was not mentioned in the descriptive lists of vegetables until the thirteenth century.

At the present time chicory is grown mainly for its leaves used in salad and for its root as an adulterant for coffee. In Europe the green leaves are used as potherbs to some extent.

Culture.—When grown for salad the seed is usually planted in spring or early summer in rows 15 to 18 inches apart and the young plants thinned to 4 or 5 inches. Too early planting may result in development of the flower stalk and a root of no value for forcing. Any soil suitable for beets, carrots and parsnips is satisfactory for chicory. The cultivation and care throughout the growing season is the same as for parsnips. On the approach of cold weather the roots are lifted, or plowed out and

the tops cut off about 2 inches above the crown. The roots are then stored in a cool place where they will remain until needed.

Forcing.—When chicory is used as a food in the United States it is grown largely as a forced crop, and a pure forcing strain should be selected. The crop may be forced under greenhouse benches, in cellars or out of doors. A temperature of 50 to 60 degrees is usually maintained. At a higher temperature the heads are not so solid and there is a tendency to shoot up too rapidly.

The roots usually vary considerably in size and should, therefore, be graded before they are planted. It is desirable to make three or four grades based on length and size. Roots of each grade should be cut to a uniform length so that all of the crowns will be covered to the same depth. The size of the head corresponds to the size of the root used. Very large roots produce large heads many of which are often made up of small divisions. Some good, solid heads develop from the very large roots, but they are generally too large for the best market use. Medium to large roots produce heads of the best market size while small roots yield too many small straight heads. A head 4 to 5 inches long and weighing 2 to 3 ounces is the most desirable.

In preparing the roots for forcing the slender tips are cut off. They may be taken from storage for forcing at any time from late fall until spring, and for a succession of heads, new plantings should be made every two or three weeks. The roots are set in a trench in a sloping direction with the crown about even with, or below, the surface. They are placed close together and the crowns are covered with fine soil, sand or sawdust to the depth of 6 to 8 inches. This covering excludes the light and prevents the leaves, forming the head, from spreading, making the head solid and compact. Before covering the roots and the soil below should be watered. One or two later waterings may be necessary but the soil above the crowns should not be soaked. With the proper temperature three to four weeks are usually required to develop good heads, but at high temperatures the heads will push through the covering earlier.

Good chicory may be grown in outdoor trenches. These trenches should be at least 18 inches deep and 12 to 18 inches wide. The roots are set and covered as described above. Over the covering of sand, soil or sawdust is placed fresh horse manure to the depth of about 2 feet and extending about 1½ feet on either side of the trench. The manure furnishes the heat and protects the heads against freezing.

Chicory is harvested by cutting off the head at the base. The outside leaves are usually pulled off and the heads are packed in baskets. The French and Belgian product is shipped in 20-pound baskets with the heads packed in layers. A smaller package is desirable and the 3-pound climax basket has been used in this country.

PARSLEY

Parsley (*Petroselinum hortense*) is the most popular of the garden herbs grown in this country. The leaves are used for flavoring, for garnishing and to some extent for salads. The plant is a biennial, or short-lived perennial of the Umbelifferae family and is a native of Europe. It has been in cultivation for over two thousand years.

Culture.—Parsley seed is slow to germinate, and for this reason it is often sown in the greenhouse, hotbed, or specially prepared bed in the open. The young plants are then transplanted where they are to grow to edible maturity. The plants are hardy and may be set out as early as cabbage. In the North seed is quite commonly sown outdoors early in the spring and at intervals during the growing season. In the South the crop is grown mostly during the winter and spring. When grown commercially the rows are spaced about 15 inches apart and the plants given a space of 4 to 8 inches in the row.

Parsley is often grown as a forcing crop in the greenhouse, hotbed, or cold frame during the winter and spring. In the vicinity of Norfolk, Virginia acres of parsley are grown in frames during the winter for the northern and eastern markets. Near many of the large cities considerable parsley is grown in greenhouses and hotbeds for supplying the local markets.

The cultivation of parsley does not differ from that usually given other small-growing plants. Clean, shallow cultivation throughout the season is recommended.

Varieties.—There are two distinct forms of parsley grown for its foliage, the plain leaved and the curled, the latter being the most popular in this country. The best known varieties are Moss Curled, Extra Double Curled, Fern-leaved and Curled Dwarf. The plain-leaved parsley has as good flavor as the curled, but is not as attractive, hence is little grown. In addition to the forms grown for their foliage a turnip-rooted parsley is grown for its edible root. This is grown in the vicinity of some of the large cities, where it is sold mainly to the foreign population. The culture of turnip-rooted parsley is about the same as for carrots.

Harvesting.—In harvesting parsley only a few leaves are picked from a plant at one time. By this method the plant continues to produce a marketable product for several weeks.

The leaves are tied into small bunches for market, and, when shipped long distances, the bunches are packed in baskets, hampers, or barrels. Crushed ice placed in the package as described for spinach is an advantage in preventing heating and decaying in transit.

CHERVIL

Chervil or salad chervil (*Anthriscus Cerefolium*) is an annual plant very much like parsley, popular in Europe, but little grown in this

country. It is used for garnishing and flavoring. The curled-leaved varieties are the most popular because of their attractive appearance.

The plant is grown in very much the same way as parsley and the leaves are ready in six to eight weeks from seed sowing. It does not thrive in hot weather, therefore, should be grown as a spring or fall crop. It is hardy and will withstand the winters in the North if given protection of a cold frame, or even a covering of straw or some similar material. The plant grows to the height of 18 inches to 2 feet, but the foliage is usually harvested when young.

CRESS

Cress, Garden Cress (*Lepidium sativum* Linn.) is an annual of the Cruciferae or mustard family and is a native of Europe. It is a cool-weather plant grown for its root leaves. Seeds are sown as soon as the ground can be prepared in the spring. A cool, rich soil should be chosen for rapid growth is essential to good quality. The plant quickly runs to seed in hot weather. Cress seed is usually planted in rows 12 to 15 inches apart and the plants thinned as needed for the table.

The leaves are used in salads and garnishings and are usually ready for use in six to eight weeks from the sowing of the seed. If the leaves are removed without injuring the crown the plant continues to bear.

Other species of cress, belonging to the genus Barbarea, are rarely grown in this country, although they are cultivated to some extent in Europe. The spring cress (*B. verna*) is a biennial, but when grown under cultivation it is treated as an annual, or as a winter perennial, the seeds dropping in summer produce plants which send up flower stalks the following spring.

WATER CRESS

Water cress (*Roripa nasturtium-aquaticum*) is a perennial, rooting at the joints, thriving in very moist places and in running water. It is readily propagated by seeds and by pieces of the stem. While water cress is commonly grown along streams or ditches fed by springs it can be grown in moist soil in the garden, in hotbeds, or in greenhouses. When grown in gardens or in forcing structures the seeds may be started in a well-prepared seed bed and the young plants transplanted, or pieces of stems may be used for starting a bed. As commercially grown, out of doors, it is a common practice to plant along streams or ditches, a stream often being divided so as to extend the planting area. It is important that the water be pure and clean. When once established it will persist indefinitely if it is not harvested too closely.

CORN SALAD

Corn salad or Fetticus, sometimes called Lams lettuce (*Valerianella olitoria*) is used both as sald and potherb, but chiefly the former. It is a

native of Europe, where it grows wild among the corn (grain), hence the name "corn salad." It is a hardy cool-season crop which is of easy culture except during hot weather. For an early crop in spring the seeds are often sown in the fall, in drills 18 inches apart and the planting covered with a mulch of straw or other material. The leaves may be blanched, but they are usually eaten green. Corn salad is sometimes cooked and served like spinach, but more often it is used as a salad. It is rather tasteless and is not as popular as other salad crops.

CHAPTER XX

COLE CROPS

CABBAGE
CAULIFLOWER AND BROCCOLI
BRUSSELS SPROUTS
KOHL-RABI
CHINESE CABBAGE

All cole crops are hardy and thrive best in cool weather, being grown in the South mainly during the winter. The crops in this group are closely related, belonging to the same genus (Brassica) and most of them to the same species. The cultural requirements for all the crops in the group are very similar and many of the same diseases and insects attack them all. Kale and collards are cole crops but for convenience they are included with other potherbs or greens (Chapter XVIII).

CABBAGE

Cabbage is by far the most important member of the genus Brassica grown in the United States and, in fact, is one of the most important of all vegetables. According to the 1920 Census Report 123,994 acres were grown for sale in the United States in 1919 and the value of the crop was $21,848,112. Ten states produced two-thirds of the total crop of cabbage and one of these, New York, produced nearly one-fourth of the whole

TABLE XXVII.—ACREAGE AND VALUE OF THE CABBAGE CROP IN 1919 IN TEN LEADING STATES
(Census Report, 1920)

State	Acres	Value
New York	30,555	$4,906,249
Wisconsin	11,955	1,478.781
Pennsylvania	7,718	1,669,971
Virginia	5,443	1,238,320
California	5,422	953,658
Florida	4,501	1,139,361
Texas	4,329	724,108
Michigan	4,297	613,265
Ohio	4,240	825,707
New Jersey	4,079	618,495

acreage. The acres grown and the total value of the crop in each of the ten states are shown in Table XXVII.

History and Taxonomy.—Cabbage is found in the wild state on the chalk rocks of the sea coast of England, on the coasts of Denmark and Northwestern France, and in various other localities from Greece to Great Britain. It has been known from earliest antiquity and was probably in general use 2,000 to 2,500 B. C. It was held in high esteem by the ancient Greeks and is said to have been worshipped by the Egyptians. Cabbage was introduced into European gardens in the 9th century and into the United States in the early days of colonization.

Cabbage belongs to the Cruciferae or mustard family. It is known by the technical name *Brassica oleracea* var *capitata* Linn. The wild cabbage plant is herbaceous, usually perennial, but sometimes biennial. The cultivated cabbage is biennial, although grown as an annual crop. There is great variation among the cultivated types of cabbage. They differ in size, shape and color of the leaves, and in size, shape, color and texture of the head.

Soil Preferences.—Cabbage is grown on all types of soils from the sands and mucks to the heavy soils. For a very early crop sandy or sandy loam soils are considered best, while for a late crop, where a large yield is the most important consideration, clay loams and silty soils are preferred. A good muck soil is very satisfactory for late cabbage. A sandy soil is excellent in the spring, when moisture does not become a limiting factor, but in late summer such a soil is not at all desired. Early crops are grown mostly on light soils while the late crop is grown on heavy soils, which are most retentive of moisture and are richer.

Soil Preparation.—For early cabbage in the North fall plowing is important since it is desirable to plant very early in the spring. In the South cabbage is planted in the fall or winter depending upon the locality and climate, therefore, summer or fall plowing is essential. Fall plowing in the North is especially desirable where sod land is to be used. The vegetable matter will then be partially decayed by spring and the soil in good condition to receive the crop.

For a late crop the preparation should be made with the idea of conserving all the moisture possible. Spring plowing is desirable in this case and the land should be harrowed at intervals to keep down weeds and to maintain a surface mulch.

Manures and Fertilizers.—Cabbage is a gross feeder, especially of nitrogen and potassium. It is considered a hard crop on the soil and there is experimental evidence to substantiate this belief. Farmers often report that corn following cabbage produces a smaller yield than when it follows corn.

The Ohio Experiment Station (*Bull.* 344; 374–384) gives results of fertilizer experiments on cabbage grown in the Marietta section 1915 to

1919. The average yields per acre for the 5 years under the various treatments are given in Table V, Chapter III. By comparing the yields of plats 3 and 6 it will be seen that 800 pounds of acid phosphate, 100 pounds of muriate of potash and 300 pounds of nitrate of soda per acre produced practically the same amount of cabbage as 16 tons of manure and 400 pounds of acid phosphate. The latter treatment is much more expensive than the former due to the cost of manure and the labor of hauling and applying.

Results of experiments on a Miami silt loam soil at the Rhode Island Experiment Station (66) are given in Table III, Chapter III. A study of the table shows that 16 tons of manure supplemented with chemical fertilizers produced larger yields than 32 tons of manure alone. Cover crops and chemical fertilizers also produced larger yields than 32 tons of manure.

On most market garden and truck soils a larger amount of nitrogen would be desirable. Many market gardeners and truck growers use a ton or more of high-grade fertilizer per acre on cabbage. A good formula on sandy loam soils is 5–10–5 and this may be applied at the rate of one ton per area where manure is not used. If manure is used in large quantities, phosphorus is the main element to be supplied by commercial fertilizers, although some readily available nitrogen is desirable to give the plants a quick start in the spring.

For late cabbage, grown on heavy soils in rotation with general farm crops, especially when manure is used in the rotation, an application of 500 to 750 pounds of acid phosphate gives good results. Many growers apply 10 to 20 tons of manure and 750 pounds of acid phosphate to the acre for late cabbage. Where manure is not used on cabbage, or in the rotation, 1,000 to 1,200 pounds of a 4–12–4 mixture would ordinarily be profitable.

Cabbage requires a large amount of moisture, therefore the late crop, which is produced during the dry portion of the season, requires a soil containing considerable humus. If manure is not available to supply humus some green-manure crop should be turned under. This is also important for the early crop on the sandy and sandy loam soils.

On a good type of muck soil an application of 200 to 400 pounds of muriate or sulphate of potash alone produces large yields of late cabbage. Results of experiments conducted at North Liberty, Indiana, by the U. S. Department of Agriculture and the Indiana Experiment Station 1915–1917 show the importance of potash.

These results as summarized by Beattie (10) are given in Table XXVIII.

The results are not entirely consistent but they show the importance of potash.

TABLE XXVIII.—AVERAGE YIELD OF CABBAGE (FLAT DUTCH VARIETY) IN FERTILIZER EXPERIMENT AT NORTH LIBERTY, INDIANA, 1915–1917

Fertilizer treatment, lb. per acre	Yields lb. per acre
None	21,531
Nitrate of soda 200 Tankage 200	22,711
Acid phosphate (14 per cent) 457	20,939
Muriate of potash 200	35,281
Muriate of potash 400	42,330
Sulphate of potash 200	32,585
Manure 30,000	37,770
Limestone 2,000	24,842
Muriate of potash 200 Acid phosphate (14 per cent) 457	37,377
Muriate of potash 400 Acid phosphate (14 per cent) 457	42,457
Nitrate of soda 200 Tankage 200 Muriate of potash 400	38,792
Muriate of potash 400 Manure 30,000	43,846
Limestone 2,000 Manure 30,000	41,772

Growing Plants.—There are several distinct methods of growing cabbage plants for the early crop: (1) Sowing seed outside in the fall in the South; (2) sowing seed in the cold frame late in the fall or early winter and transplanting to the field direct from the seed bed; (3) sowing seed in a hotbed early in the spring and transplanting direct from the seed bed; (4) sowing seed in the greenhouse or hotbed and transplanting the plants at least once before setting them in the open.

In many sections of the South, especially along the Atlantic Coast and in the southern tier of states, the most common practice is to sow cabbage seed in an open bed in the fall and to set the plants in the field after 6 to 10 weeks. The seed is sown with a seed drill. October is usually the month for seed sowing where this method is followed and the plants are commonly set out in December. In the cooler sections of the South, and in regions where there are great variations in temperature, seed is often sown in cold frames in late fall and early winter and the plants set out in February.

Sowing seed in the hotbed in March and setting the plants direct to the field without transplanting is practiced to some extent in the North, but this method is not satisfactory where earliness is of prime consideration. Plants grown in this way are usually not well hardened, and there-

fore will not withstand freezing. Those that survive are likely to be weak and spindling.

The most common method for growing early plants in the North is to sow the seed in a greenhouse or hotbed in January or February and to transplant the seedlings, spacing them 1½ to 2 inches apart each way. Some growers transplant cabbage plants twice before setting them in the field, giving them more space at the second transplanting. If more space could be given at the first transplanting better results would be secured without additional transplanting.

Cabbage plants for the late crop in the North are grown in the open. The seed is sown about 5 weeks before time for planting in the field. A good, loose soil should be selected for the seed bed and this should be thoroughly prepared. Heavy fertilization of the seed bed is not desirable since a rich soil is likely to produce too rapid growth. Where the cabbage maggot is present the bed should be screened, or the plants treated with a solution of corrosive sublimate 2 to 4 times while still in the seed bed.

The amount of seed required for an acre of land depends upon the viability of the seed, the care taken in preparing the seed bed and the method of growing plants. If the seed bed is well prepared and given good care, more plants will be available from a given amount of seed than if the soil is not well prepared and poor care is given. A pound of seed of high viability will furnish ample plants for 4 acres of land, if the plants are grown in greenhouses or hotbeds and the seedlings are "pricked out." When seed is sown in outdoor beds and the plants are transplanted direct to the field it is not safe to expect more than enough plants for 2 acres from 1 pound of seed. Many of the plants are thrown away because they do not develop properly due to crowding in the seed bed.

Planting.—Cabbage plants, which have been well hardened, will withstand a temperature of 10 to 15 degrees below freezing if not of long duration. In regions where the temperature seldom goes much below 32 degrees F. it is safe to set cabbage plants in the fall or early winter. In the North well-hardened plants may be set out as early in the spring as the ground can be prepared or as soon as the danger of hard freezes is over. Late cabbage in the North is set out the latter half of June and in July depending upon the earliness of fall freezes. About 4 months should be allowed late cabbage to mature.

The spacing of the plants depends largely upon the variety. Small-growing varieties like Jersey Wakefield are set 12 to 15 inches apart in the row with the rows 2 to 3 feet apart. Larger varieties like Succession, Early Summer and Copenhagen Market are set 18 by 28 to 18 by 36 inches. Very large cabbages such as Flat Dutch requires more room and the plants are set at least 2 feet apart in the row, with the rows 3 to 3½ feet apart. Myers' (104) results in Pennsylvania seem to indicate that close planting increases the total yield, but delays maturity and

decreases the size of the heads of Jersey Wakefield, Early Spring and Copenhagen Market varieties. However, the results were not entirely consistent and, therefore, should be considered as giving only an indication of what may be expected. The best plan seems to be to plant rather close in the row and to allow a liberal space between the rows for convenience in cultivating.

Cabbage plants are set by hand and by means of transplanting machines. By the hand method the opening for the plant may be made by use of a dibble, trowel, or by means of a small plow. When the plow is used, the plants should be set immediately before the soil dries out. Hand transplanters are also used. The hand transplanter has a water attachment so that water may be applied around the roots as the plant is set. Machine transplanters are used to a large extent where considerable areas are planted. These machines do better work than is usually done by hand. They open the furrow, apply water around the roots and pack the soil around the plant all at one operation.

When setting out cabbage plants from the seed bed during the summer only the strong, stocky plants should be used because many of the weak ones do not withstand the shock of transplanting and many others make a slow growth. In an experiment in Pennsylvania (104) plants were graded according to size at the time of planting to the field. The experiment covered 3 years, 2 years with Enkhunizen Glory and 1 year with Danish Ballhead. The average of the yields from the different grades was as follows: Small plants 12.7 tons per acre, medium 17.7 tons, ungraded 18.5 tons and large 21 tons per acre.

Cultivation.—In the cultivation of cabbage great care must be exercised to prevent destruction of the roots; therefore only very shallow cultivation should be given after the plants have attained considerable size. Many of the roots of the cabbage plant grow within two inches of the surface of the soil and these run almost horizontally. Before the plant is half grown the roots cross in the centers between the rows, and if deep cultivation is given more harm than good may be done. (See Chapter X "Cultivation.") Sufficient cultivation should be given to keep down weeds and probably to maintain a soil mulch while the plants are small. After the plants are half grown cultivation is not so important unless weeds are troublesome. Cultivation should cease when it is impossible to perform the operation without injuring the plants, since there is evidence that little moisture is lost from the soil by evaporation from the surface, when the plants are large. There is also evidence that cultivation destroys the roots near the surface.

When the plants are small cultivation may be done by gang cultivators or by any ordinary shovel cultivator, but when the plants get larger only light cultivators should be used. A harrow-like cultivator or one of the Planet Junior 15-tooth type, may be used to good advantage after

the plants are well established. In fact if the ground has been well prepared, the light cultivator is best for all cultivation.

Hand hoeing or hand weeding is usually necessary to keep the weeds down between the plants in the row. This is especially important in the spring when weed growth is rapid.

Types and Varieties.—Seedsmen list a large number of varieties of cabbage but only a few of them are of much importance. Myers and Gardner (103) report that in 1915 fifty-four representative seedsmen listed 243 varieties, but of these only 35 were listed by more than ten seedsmen and 174 varieties were listed by not more than two seedsmen.

The different varieties grown in the United States have been classified in various ways. No classification that has been attempted is entirely satisfactory, but the one suggested by Myers (106) is probably the best. This is similar to the classification suggested by Allen ("Cabbage, Cauli-

Fig. 20.—Three varieties of early cabbage: 1, Jersey Wakefield; 2, Charleston Wakefield; 3, Copenhagen Market.

flower and Allied Vegetables" page 54), but three groups are added to those mentioned by Allen. Myers suggests eight groups as follows:

1. The Wakefield and Winningstadt group.
2. The Copenhagen Market group.
3. The Flat Dutch or Drumhead group.
4. The Savoy group.
5. The Danish Ballhead group.
6. The Alpha group.
7. The Volga group.
8. The Red Cabbage group.

The Wakefield and Winningstadt group includes varieties having small pointed heads (Fig. 20). The plants mature early and are grown chiefly for the early crop. The best known varieties of this group are Jersey Wakefield, Charleston Wakefield and Early Winningstadt. Early Winningstadt is a good home garden variety but is not grown to any great extent in the United States, except in southern California where it is an important variety.

The Copenhagen Market group is important largely because of the variety Copenhagen Market (No. 3, Fig. 20), which is the most important

early, roundhead cabbage grown in the United States. It is nearly as early as the Jersey Wakefield and the heads are much larger. The head is round and compact, having few outer leaves and a small core. The leaves are small to medium in size, light green in color and covered with a heavy bloom. The stem is short. This is one of the most important early varieties in the North and is also used for mid-season and early fall crops.

The Flat Dutch group is distinguished from all others by the flat heads (Nos. 5 and 6, Fig. 21.). The plant is medium to large; the outer leaves are large and numerous, curving inward and inclosing the head loosely. The color is light green. The heads are large, flat and fairly solid. The leaves forming the head fold over each other at the center. Varieties in this group differ considerably in the length of time required to mature.

Fig. 21.—Three varieties of midseason cabbage: 1, Enkhuizen Glory; 2, Early Summer; 3, Succession.

The Savoy group is characterized by foliage which is very much blistered or wrinkled. The foliage is dark green and has very little bloom. The quality of this group is considered superior to all others, but it is not of much commercial importance although long-cultivated. The most important varieties are Savoy, Drumhead Savoy and Perfection Savoy.

The Danish Ballhead group contains the most important varieties of cabbage, the best known variety being the Danish Ballhead, also known as Hollander, Danish, Danish Roundhead and many other names. The mature plant is of medium size; the outer leaves are few in number, curve inward to some extent, light green in color and are covered with a fairly heavy bloom. The head leaves are of fine texture and reach well past the center. The head is of medium size and very solid. It is the best keeping variety grown in the United States and is used to a greater extent than all other varieties of late cabbage.

The Alpha group contains the earliest varieties. The heads are smaller than Wakefield, round and very solid. The plants are small and may be planted close together. The group is of little commercial importance, and no well-known varieties are included in it. Miniature Marrow and St. John Day are perhaps the best known.

The Volga group is best represented by the variety Volga. The mature plant is large and has few outer leaves, which curve outward; leaves large and thick; color steel-blue. The head is of medium size, globular but somewhat flattened; the head leaves extend a short distance past the center thus giving it a bald appearance. The head is solid on top, but rather open below.

The Red Cabbage group is distinguished from all others by its deep purplish-red color. Otherwise the plants show considerable resemblance to the Danish Ballhead but the yield is usually smaller. The best known red varieties are Rock Red or Mammoth Rock Red, Red Dutch and Red Danish or Danish Red. These are probably different strains of the same variety.

Diseases.—There are several very serious diseases of cabbage, the most important being club-root, root-knot (nematodes), yellows, black-rot and black leg. A serious infection of some of these is sufficient to make cabbage growing unprofitable, and in many instances results in total loss of the crop.

Club-root (*Plasmodiophora brassicae* Wor.) is produced by the invasion of a slime mold on the roots. Plants affected by this disease show, in the earlier stages of growth, a wilting of the foliage on sunny days, with recovery toward evening or on cloudy days. The roots of affected plants show characteristic swellings, which often become very large. The mass of thickened malformed roots presents a clubbed appearance.

The organism is a soil parasite which thrives best in an acid soil. Correcting the acidity of the soil by applications of lime is the only practicable control measure used. The lime should be applied a few months before planting the cabbage, preferably in the preceding fall.

The seedlings are very susceptible to the disease, and caution should be taken to grow plants on uninfected soil, or to disinfect the seed bed. Diseased plants should be destroyed by burning. A long rotation, in which no cruciferous plants are grown, is of value in controlling this disease.

Root-knot.—This is a disease caused by a parasitic eelworm (*Heterodera radicicola* (Greef) Mull.). The parasite penetrates the roots and causes irregular swellings, which are sometimes confused with club-root. Root-knot, as a rule is characterized by smaller swellings than club-root. More of the feeding roots are affected and the knots are located nearer the tips of the roots. Root-knot is not serious in the North but is very destructive to nearly all kinds of crops in the South.

Crop rotation is the most effective means of controlling this disease, but in order to starve out the parasite the alternating crops grown must be immune or resistant to root-knot. A rotation of at least three years accompanied by clean cultivation, should be practiced. Harter and Jones (63) state that there are 480 different species of plants known to be susceptible to root-knot, including many cultivated plants and numerous

weeds. The following crops are listed by them as being immune or highly resistant to the disease, and can be used in the rotation; corn, winter oats, rye, timothy, pearl millet, sorghum, wheat, crab grass, the Iron and Brabham cowpeas, velvet beans, peanuts and beggar-weed. The following crops should be avoided in the rotation; alfalfa, vetch, soybeans (except Laredo) cowpeas (except Iron and Brabham) clover, tomatoes, cotton, okra, cucumbers, watermelons, canteloupes, celery, beans, sweet potatoes, tobacco, potatoes and all crucifers.

Yellows.—This disease is recognized in the field by the lifeless, yellowish-green color, which shows up in two to four weeks after transplanting. The plants are stunted and often are warped and curled, due to the attack beng more severe on one side of the plant than on the other. The vascular bundles of the stem and lower leaves become darkened, the color deepening as the disease progresses. Diseased plants shed their lower leaves while the plants are still attempting to grow.

Disinfection of the seed with mercuric chloride solution (1:1,000) reduces the danger of carrying the disease to new districts, but is of no practicable value if the crop is to be planted on infected soils. The germs persist indefinitely in the soil and therefore, ordinary crop rotation does not control the disease. Seed-bed infection is one of the worst dangers, hence, care should be taken to plant the seed in clean soil. The only safety lies in planting cabbage on disease-free land or in using yellows-resistant varieties, such as Volga, Houser and Wisconsin Hollander. The last named is a disease-resistant selection from the Hollander variety developed by the Wisconsin Experiment Station.

Black-rot.—This is caused by a bacterium (*Bacterium campestre* (Pammel) Erw. Sm.) and appears in the plant at any stage of growth. The yellowing of affected leaves followed by a blackening of the veins is the first indication of the disease. Later the plants show a dwarfing or one-sided growth of the head, or, if the disease is severe and starts early in the season there may be no head formed. The heads sometimes rot and fall off. A cross-section of the stem of affected plants shows a brown or black ring corresponding to the woody tissue. Often the blackening of the veins of the leaf can be seen through the outer tissues.

No sure methods of controlling black-rot are known, but the observance of certain precautions will prevent serious loss. The germs are known to be carried on the seeds therefore seed disinfection with corrosive sublimate is recommended. Soil and manure for the seed bed should be free from disease. Crop rotation is of value in controlling this disease. The rotation should be one in which no cultivated crucifers or cruciferous weeds are allowed to grow for 4 or 5 years. Live-stock should be kept out of diseased cabbage fields as they may carry the organism to disease-free fields. Diseased plants should be destroyed and not thrown on the manure heap.

Black-leg.—This disease is caused by a fungus parasite (*Phoma Lingam* (Tode) Desmax). It may invade almost any portion of the plant but the worst damage occurs when it kills the stems of the young plants in the seed bed or in the field. Infection often occurs on the stem near the ground, causing dark sunken areas. The disease spreads from these areas, gradually killing the base of the stem and roots, so that the plant wilts. The wilting of the entire plant is characteristic of the advanced stages of this disease, and the leaves adhere to the stem instead of falling off as in the yellows. In the advanced stage of the black-leg, the dead areas are covered with very small black specks, which are the fruiting bodies. These live in the soil on parts of diseased stems and leaves and may persist for two years or more.

The control measures for this disease are the same as suggested for black-rot. However, Walker (171) has recently shown that treating the seed with formaldehyde solution, mercuric chloride solution, hot water or dry heat does not entirely destroy the fungus without materially reducing germination and causing injury to the seedlings. In his experiments the disease was checked by seed treatment, but was not completely controlled even when the treatment was carried beyond the point where seed injury resulted.

Insects.—Cabbage and closely related plants are attacked by many insects including both those with chewing and those with sucking mouth parts. The important chewing insects of cabbage are the cabbage maggot, green cabbage worm, southern cabbage butterfly, cabbage looper, diamond-back moth, cross-striped cabbage worm, cabbage webworm, garden webworm, purple-backed cabbage worm, and zebra caterpillar. The important sucking insects attacking cabbage are cabbage aphis, turnip aphis and harlequin cabbage bug.

Cabbage Maggot (*Phorbia brassicae*).—The cabbage maggot is a small whitish larva of a black fly a little smaller than the common house fly. The fly deposits eggs just below the surface of the ground on or near the roots of cruciferous plants. The eggs hatch in a few days and the larvae feed on the plants for about three weeks. They first attack the rootlets and then burrow into the main root, causing the plant to wilt, and in most cases, to die. Even if the plant is not killed outright its vitality is often so weakened that only a small head, or no head at all, is formed. In the North the maggots are most destructive to early cabbage in the field and late cabbage in the seed-bed.

For the control of cabbage maggot on early cabbage in the field the most effective remedy now known is a solution of corrosive sublimate 1:1,000, or 1 ounce of the powder to 8 to 10 gallons of water. Two or three applications are made, the first one about the time the adult fly appears, which is usually soon after the plants are set. At each application about one-half cupful of the solution is applied around each plant.

Other methods of control used are tar paper discs and tar and sand mixture. Schermerhorn and Nissley (131) compared these three methods of control in five counties in New Jersey and in two tests on the Station grounds. The treatments given were as follows:

1. Corrosive sublimate, 1 ounce of powder to 10 gallons of water, two applications of about one-half cupful around each plant. The first application was made 3 or 4 days after planting and the second 8 to 10 days after the first.
2. Commercial tar paper pads placed around the plants within a few hours after setting in the field.
3. Tar and sand mixture made by mixing about one bushel of sand and one quart of water-gas tar. The mixture should be made at least a week previous to its application to prevent injuring the plants. The material was applied at the rate of about a table-spoonful around each plant. A second application was made, but this is not usually necessary.

The average percentage of plants killed by maggots in the tests in the five counties and the two tests at New Brunswick was 1.96 with corrosive sublimate, 5.33 with tar paper pads, 32.73 with tar and sand and 58.53 per cent where no treatment was given.

The costs per acre including the material and labor of applying was $29.65 per acre for two applications of corrosive sublimate, $39 for tar paper pads, and $22.50 for two applications of tar and sand.

Tar paper discs placed around the plants before the fly appears act as a repellant and prevent the fly from depositing its eggs near the plants, provided the discs do not become covered with soil. Since there is danger of covering the discs when cultivating, and it is impracticable to sweep the soil off, the corrosive sublimate treatment appears to be more satisfactory. The length of time required to place the discs around the plants is at least equal to the time consumed in making one application of corrosive sublimate solution.

For the late crop the common method of control is to screen the seed bed with cheese cloth. This prevents the female depositing eggs on or near the roots. Soaking the soil of the seed bed with corrosive sublimate solution has also given good results where three or four applications have been made. This method bids fair to replace the method of screening the bed.

Green Cabbage Worm, or Imported Cabbage Worm (*Pontia rapae*).—This worm is the larvae of a small white butterfly. Its larva is about 1-inch long and velvet green in color. It is the most destructive of the common cabbage insects, eating holes in the leaves and often burrowing into the head.

Spraying the plants with arsenate of lead, 4 pounds of paste or 2 pounds of powder to 50 gallons of water, with 4 pounds of soap to make the spray adhere to the foliage will control this pest. The poison may

be applied in the form of a dust, using 1 part arsenate of lead powder and 4 parts of air-slaked lime. It is best to apply the dust when the dew is on the plants. There is no danger from poisoning since the cabbage head grows from the inside.

Southern Cabbage Worm (*Pontia protodice*).—This insect resembles the adult of the green cabbage worm in the adult stage, but is pure white in color. The larva is strongly colored, purplish and yellow striped, with black spots. The injury done by this insect is identical with that of the green cabbage worm, therefore the same control measures are used.

Cabbage Looper (*Autographa brassica*), the larva of a moth, resembling the cut-worm moth, feeds on the foliage of cabbage and related plants. This worm can be distinguished from the others by its peculiar looping or doubling up as it crawls. It is more active than the other worms previously considered, and is, therefore, more difficult to control. In addition to attacking all cole crops it sometimes injures peas, beets, celery and lettuce. The same control measures are used for the cabbage looper as for the green cabbage worm.

Other Cabbage Worms, including the diamond-back moth, cross-striped cabbage worm, cabbage webworm, purple-backed cabbage worm and zebra caterpillar, injure the crop in much the same way as those already discussed and the same control measures are applied. The cross-striped cabbage worm bores into the head in the same manner as the green cabbage worm.

Cabbage Aphis (*Aphis brassicae*).—This is one of the species of insects commonly called plant lice. These insects are more injurious during the latter part of the season than earlier. The cabbage aphis is covered with a coat of fine waxy powder, very much like the bloom on cabbage leaves. This covering protects the insects from spray material since the liquid runs off of their waxy surface. Spraying with nicotine sulphate solution, to which soap has been added as a sticker, has been the treatment recommended during the past few years. Recent experiments have shown that dusting with nicotine preparations gives good results in the control of cabbage aphis. Parrot (113) reporting the results of experiments in New York has the following to say regarding dusting for the control of cabbage aphis:

> From the standpoint of economy and effectiveness, the most satisfactory treatment was a lime preparation (calcium hydrate) containing 2 per cent nicotine, applications being made at the rate of 20 pounds per acre with a "hand bellows duster." With power dusting machinery from 35 to 40 pounds of material were required to secure effective control. Considering the results as a whole, dusting appears to be a very promising system of treatment for controlling the cabbage aphis. . . .
>
> For control of cabbage aphis and cabbage worms we prefer, for the present, the formula which provides 5 pounds nicotine sulfate, 15 pounds powdered lead

arsenate or calcium arsenate and 80 pounds of hydrated lime. If the caterpillars are not very numerous, it is believed that the arsenical may safely be reduced to 10 pounds.

Turnip Aphis (*Aphis pseudobrassicae*), is closely related and similar in appearance to the cabbage aphis The character of damage, life history and means of control are the same as for the cabbage aphis.

Harlequin Cabbage Bug (*Murgantia histrionica*) is a true bug about $\frac{2}{5}$ of an inch long, mottled red, black or yellow. Both the adult and the young suck the juices and inject a poison into the plant. In many sections of the South, this insect is one of the most important pests. The young insects are much more easily killed than the adults, but both young and old are difficult to kill by ordinary sprays. Spraying with nicotine sulphate and kerosene emulsion is partially effective if applied while the insects are young. Other remedies are clean culture, especially in the fall, trap crops of mustard or other crops in the spring, and hand picking. All stumps and refuse of the crop should be destroyed in the fall so as to reduce hibernating shelter as much as possible. A few piles of rubbish left in the field in the fall will act as traps. After bugs have collected the piles should be burned. A trap crop of mustard will attract the bugs and they will collect on it. When the trap crop becomes infested it may be sprayed with kerosene, or strong kerosene emulsion.

Harvesting.—Cabbage which is grown for the early market is harvested as soon as it has attained sufficient size to be placed upon the market, since earliness is usually of more importance than size. The first shipments from the South usually consist of small, immature heads, but as the season advances the quality improves and the heads are closely trimmed. Midseason and late cabbage is not harvested until the heads are full size and hard.

In harvesting the heads are cut with a large knife, or, in some cases with a hatchet. The head is grasped in one hand and the plant is bent over so that the head can be cut above the outer leaves. Quite commonly the cutter takes two rows at a time, and as he cuts the heads he places them on the row to be gathered by others or he tosses them to a man on a wagon or into the wagon box. For late cabbage care is taken to prevent bruising the heads and for this reason the cutter usually places them on the row to be gathered by others, who toss them to a man on the wagon. They are carefully placed in the wagon box and hauled to the car or to the storage house.

Grading.—Cabbage is seldom carefully graded, the common practice being to include in one grade all marketable heads. However, grading would greatly facilitate orderly marketing and undoubtedly increase the demand. The United States Bureau of Markets proposes two grades, U. S. No. 1 and U. S. No. 2, with specifications as follows:

U. S. No. 1 shall consist of heads of cabbage which are of one type, fairly firm and well trimmed; which are not soft, withered, puffy or burst; which are free from soft rot, seed stems and from damage caused by discoloration, freezing, disease, insects or mechanical or other means.

In order to allow for variations incident to proper grading and handling, not more than 10 per cent, by weight, of any lot may be below the requirements of this grade.

Any lot of cabbage consisting of heads of more than one type but which meet all other requirements of U. S. No. 1 may be designated U. S. No. 1 Mixed.

U. S. No. 2 shall consist of heads of cabbage which do not meet the requirements of the foregoing grade.

In addition to the statement of grade, any lot may be classified as Small, Medium, Large, Small to Medium, or Medium to Large, if 75 per cent, by weight, of the heads conform to the following requirements for such sizes:

	Small	Medium	Large
Pointed	Under 2 lb.	2 to 4 lb. inclusive	Over 4 lb.
Other types	Under 4 lb.	4 to 6 lb. inclusive	Over 6 lb.

Packing.—Cabbage grown for the local market is seldom packed but is loaded without containers into the wagon or truck. When grown as a truck crop, the heads are packed into boxes, crates or barrels. There are many types of cabbage crates in use, Downing (38) listing twenty in common use. These vary in capacity from 4,224 cubic inches to 13,824 cubic inches. Downing suggests that four types as given in Table XXIX would meet the needs:

Table XXIX.—Four Types of Cabbage Crates Suggested by Downing

Type	Inside dimensions, in.	Length of slat, in.	Capacity, cu. in.
Atlantic Coast type	12 × 18 × 33	36	7,128
Mississippi Valley type	16 × 16 × 28	30	7,168
Colorado type	21 × 22 × 24	24	11,088
California type	18 × 18 × 23¾	24½	7,695

Reducing the number of types of crates to four would make for economy in manufacture and would eliminate a great deal of confusion which now prevails.

The veneer barrel with a burlap cover is used to a large extent in the Norfolk-Portsmouth region of Virginia, although the crate is also used.

Cabbage grown for the kraut factory and for the winter market is usually loaded into cars without containers. In mild weather the heads are loaded into cattle cars and box cars, while in cold weather refrigerator cars are used.

Storing.—A large part of the late crop of cabbage grown in the North is stored for winter use. Outdoor storage is used for cabbage grown for home use and to some extent for the market crop, but a large part of the commercial crop is stored in special storage houses.

The essentials of success for keeping cabbage in storage are: (1) A good storage variety, (2) freedom from disease, and injury of any kind, (3) a relatively uniform temperature near the freezing point and (4) moderate degree of humidity, enough to prevent wilting but not so moist as to cause condensation.

A good storage variety of cabbage is one with compact, hard heads such as the Danish Ballhead.

Heads that are diseased when harvested will not keep as well in storage as those that are free from disease. Even if the particular disease present does not continue to develop in storage the diseased areas give a good opening for some of the storage rots. For the same reason mechanical injury caused by rough handling is likely to increase loss and shorten the storage period.

The lower the temperature the longer cabbage will keep, provided the heads do not actually freeze. In fact, slight freezing does not cause serious injury. Cabbage will not freeze in a room where the air temperature is 32 degrees F., therefore it is safe to maintain that temperature.

Moderate humidity in the storage house is important since the common storage rots develop rapidly in a very moist atmosphere, and wilting occurs under very dry conditions. In many storage houses the greatest problem is to control the humidity. In some houses a drying agent such as calcium chloride is used to take up the moisture.

Outdoor storage by various methods is employed for keeping cabbage for home use, and for market for relatively short periods. The heads are sometimes cut from the stalks and stored in conical pits in much the same manner as root crops. Another common method is to pull the plants roots and all and place them in a pit with their heads down. In Maryland and Virginia a common method used is to pull the plants and set them side by side with the roots down in a shallow trench, the length of which corresponds to the width of the bed. The bed may be any width up to 8 or 10 feet and as long as necessary to hold the number of cabbages to be stored. After the first trench is filled with cabbage a furrow is thrown against the roots and stalks and the dirt packed around them nearly up to the heads. A second row is set in the bottom of the second furrow or trench and the operation repeated until all of the plants are stored. Around the bed a frame of rails, boards or poles is erected

about 2 feet high. The outside is banked with earth and the top is covered with straw, hay or corn stover placed on poles laid across the bed. Provision should be made for getting into the bed to remove the cabbage as needed. The heads are cut off and the roots left in position. In the spring the stalks produce sprouts which are prized as greens.

It is impossible completely to control the temperature and humidity in any type of outdoor storage and in addition to this it is very inconvenient to remove the cabbage when wanted. For these reasons most commercial cabbage is stored in specially constructed warehouses. These

Fig. 22.—Interior of a cabbage storage house, showing driveway through center and heads of cabbage placed on slatted shelves on both sides of the driveway. (*Courtesy, U. S. Department of Agriculture*).

houses are built above ground and are usually low. The house must be well built to prevent rapid changes of temperature on the inside.

The walls of the house, if of brick, have two tiers with an air space between, and when made of wood three layers of boards and two or more layers of heavy paper. Two air spaces 4 to 6 inches wide are left in the walls. The ceiling, or roof is quite well insulated, there being usually two layers of boards and two layers of heavy paper with an air space between the outer and inner layers.

Ventilation is provided by means of openings through the walls near the ground and ventilators through the roof. In a wood-frame house, 35 by 77 by 25 feet, at Apulia, N. Y. there are 8 openings 1 by 1 foot near the floor and 8 windows 2 by 3 feet near the top of the walls. Seven ventilators 1 foot in diameter extend through the roof. There are two

large double doors, one at each end of the house. All openings are made in such a way that they can be made nearly air tight.

Large storage houses usually have passage ways through the center sufficiently wide to admit a wagon or truck for convenience in loading and unloading. The heads of cabbage are placed in narrow bins or on shelves as shown in Fig. 22. Where bins are used they should be narrow, preferably not over 4 feet, and the depth should not exceed 6 or 7 feet. The length from front to back may be 18 to 20 feet. In some houses bins are placed one above the other and this is satisfactory if provision is made to take care of drip from the upper bins. Shelves are better than bins but they are more expensive, and take more space.

The shelves may be made for one, two or more layers of heads. With either bins or shelves there should be air spaces between them and the walls of the house, also under them and between the rows of bins or shelves. Bins are usually made by nailing slats to both sides of 2 by 4-inch uprights so that there is a 4-inch air space between bins. The slats are placed at least 1 inch apart. The floor of the bins should be raised at least 4 inches from the floor of the house and the boards or slats should be separated so as to allow air to circulate up through the heads of cabbage.

CAULIFLOWER

Cauliflower is grown for its white tender heads formed by the shortened flower-parts. The crop thrives best in a cool, moist climate and is grown in a large way in relatively few localities such as on Long Island; in Erie County, New York; and in California. In California it is grown in winter and on Long Island and in other sections of the North mainly in late summer and fall. Cauliflower is much more particular as to climate than cabbage. It is not as hardy and will not stand as much heat. During very hot weather cauliflower heads will not develop. In most regions it is grown in spring and early summer; or in the fall.

The value of cauliflower grown for sale in the United States in 1919 was $1,328,415, and this was produced on 6,513 acres. Two states, California with 3,668 acres valued at $641,161 and New York 1,640 acres with a value of $338,040, produced over 80 per cent of the commercial cauliflower crop.

Soil Preferences.—Where the weather conditions are favorable cauliflower can be grown on almost any kind of soil. A deep rich soil is desirable. In some regions, as on Long Island, a sandy loam is preferred. Low well-drained bottom lands are often chosen in order that the plants may have a constant supply of moisture.

Thorough preparation of the soil is very important in growing cauliflower. Where the crop is started in the summer it is often possible to

grow some other vegetable before time for setting out the cauliflower plants. If, however, this is not done it is desirable to plow early and to keep the land harrowed until the plants are set out. This practice conserves soil moisture.

Manures and Fertilizers.—On sandy loam soils, manure is very important and should be used if available at a reasonable price. If manure is not available some green-manure crop should be turned under to supply humus. The cauliflower crop is usually quite heavily fertilized. One ton or more of high-grade fertilizer per acre is commonly used. On Long Island a common formula is 5–7–5 and the usual application is at least 1 ton to the acre. One-half of the nitrogen is usually in the form of nitrate of soda and the remainder in fish scrap or tankage. In most regions either a 4–8–4, 5–10–5, 5–7–5, 5–8–8 or 6–8–5 fertilizer mixture is used. For cauliflower in Louisiana Tiebout (164) recommends a "liberal application" of well-rotted stable manure, and a ton of fertilizer containing two parts high-grade acid phosphate and one part cottonseed meal, and in addition occasional dressings of nitrate of soda. The fertilizer alone would supply 213 pounds of phosphoric acid (P_2O_5) or the equivalent of 1,333 pounds of 16 per cent acid phosphate, certainly more than the crop could possibly use. In fact, most growers apply more fertilizer to cauliflower than it seems possible for the crop to utilize. Fifteen hundred to 2,000 pounds of a 5–7–5 mixture to the acre would seem ample on any soil suitable for cauliflower production.

Seed.—The importance of good seed can scarcely be over-emphasized. Poor strains are expensive at any price, for these will not produce good marketable heads under the most favorable conditions. Most of the cauliflower seed used in the United States is imported, mainly from Denmark. Some excellent strains have been obtained from some of the large dealers in Copenhagen, Denmark. Two of the large cauliflower associations in New York State are buying this seed direct from Copenhagen dealers and are well satisfied with the strains.

The retail price of good cauliflower seed is very high, $2 or more an ounce, but it is better to give this price than to plant inferior strains. However, the best seed grown in Denmark can be secured for much less than this.

Growing Plants.—Cauliflower plants are grown in very much the same manner as cabbage plants. In the North seed for the early crop is sown in the greenhouse or hotbed and the plants transplanted as described for cabbage. Cauliflower seed is not sown quite as early as cabbage. Seed for the general crop in California is sown in open beds. In the eastern part of the United States the seed for the late crop is sown about the same time or a little later than late cabbage and the plants are handled in much the same manner.

In Louisiana, Tiebout tried sowing the seed in the field where the plants were to mature and the results were quite satisfactory. His method consists of sowing ten to fifteen seeds at the distance the individual plants are to stand and covering them with fine soil by means of a hand rake. Rolling the seed bed with a light roller drawn by hand was found to be quite helpful in assuring germination. After the seedlings appear above ground each hill is given light cultivation with a four-tine hoe. Two or three light applications of nitrate of soda around the hills at intervals of 10 days or 2 weeks are recommended. At the time cauliflower plants are set in the field in Louisiana (August and September) it is very hot and a good stand of plants is secured only with great difficulty hence the method of planting the seed direct. This method is sometimes used in growing late fall cabbage in sections of the South.

Planting.—Plants for the early crop in the North are usually set out as soon as the danger of hard frosts is over. The late crop, in regions where severe freezing occurs is planted in time for the heads to mature before the arrival of very cold weather. On Long Island and in the Buffalo, New York, region the planting is done the latter half of July and the first part of August. In the South and in California cauliflower is grown as a fall and winter crop. In California the plants are set out any time from about July 1st until fall.

The distance for planting varies somewhat, depending upon the variety and the richness of the soil. The rows are usually about 3 feet apart and the plants are set 18 to 30 inches apart in the row. The methods of planting are the same as for cabbage.

Cultivation.—In the cultivation of cauliflower the same precautions should be taken as suggested for cabbage for the root systems of the two crops are similar. Deep cultivation is often practiced when the plants are small, but later on shallow cultivation is given. The weeds should be kept down at all times.

Diseases and Insects.—Cauliflower has the same diseases and insects as cabbage and the same control measures are used except the spraying with arsenicals after the cauliflower head is formed. It is not safe to use arsenical sprays on cauliflower after the head is formed because of the danger from poisoning. While this danger is rather remote it is best to take no chances.

Blanching.—A perfect head of cauliflower is pure white. To secure this it is necessary to exclude the sunlight. While the head is small it is protected by the small inner leaves which curve over it, but before it is full grown these leaves begin to lift and some other means of covering is usually necessary. The usual method is to bring the outer leaves up over the head and tie them with straw, raffia, twine or tape of some kind. By using a different kind of material or a different colored twine

each day for several days it is easy when cutting to select those that have been tied the longest. Sometimes two outer leaves are broken over to protect the head but this method is not as satisfactory as tying.

The length of time for the blanching of the head depends upon the weather. In the hotter part of the season when the plants are growing rapidly, two or three days, will be sufficient while in cold weather 8 to 12 days may be required. If left too long during hot weather the leaves begin to rot and discolor the head. In cool weather the heads begin to push up their flower stalks and assume a "riced" condition if left too long and this reduces their value. They may even begin to branch and this renders them worthless except for pickles. Examination of the heads should be made every day during hot weather and at intervals of every two or three days in cool weather. It is seldom necessary to examine more than an occasional head of any particular day's tying, as all the heads will be ready about the same time. However, if the heads are developing unevenly it is necessary to examine every head.

Harvesting.—Cauliflower is harvested when the heads attain the proper size and before they begin to "rice" or become discolored. Medium sized heads are in greatest demand. In harvesting the plant is cut off at the ground with a large sharp knife. The heads are seldom trimmed in the field, but the plants are loaded on a wagon and hauled to a packing house or shed. Care should be taken to prevent injury to the heads in handling.

The heads are trimmed with a long sharp knife cutting squarely across the leaves, leaving ½ inch to 1 inch projecting above the head. The stubs left protect the head from injury by rubbing against the crate. The stem of the plant is cut off so as to leave at least one circle of outer leaves and the smaller inner leaves.

Grading.—Cauliflower heads are usually graded into at least two grades and sometimes three. The U. S. Bureau of Markets recommends three grades: U. S. No. 1, U. S. No. 2 and U. S. No. 3.

U. S. No. 1 shall consist of compact heads of cauliflower which are not discolored, ricey, fuzzy or overmature; which are free from damage caused by dirt or other foreign matter, bruises, disease, insects, mechanical or other means. Attached leaves shall be fresh and green.

In order to allow for variations incident to proper grading and handling, not more than 10 per cent, by count, of any lot may be below the requirements of this grade but not to exceed one-half of this tolerance shall be allowed for any one defect.

U. S. No. 2 shall consist of heads of cauliflower which are free from disease, damage caused by overmaturity, discoloration, dirt or other foreign matter, bruises, disease, insects, or mechanical or other means.

In order to allow for variations incident to proper grading and handling, not more than 10 per cent, by count, of any lot may be below the requirements of this

grade but not to exceed one-half of this tolerance shall be allowed for any one defect.

U. S. No. 3 shall consist of heads of cauliflower which do not meet the requirements of the foregoing grades.

Packing.—Cauliflower is packed in various types of boxes, baskets, crates and barrels. The round-stave bushel basket is used in some regions, but this is not a popular shipping container. The barrel was formerly used to a very large extent on Long Island, but has been largely replaced by a crate 13 by 15 by 23 inches. In Erie County, New York a crate 8 by 18½ by 20¼ inside measurement is used. When the heads are of uniform size 11 heads are packed in this crate, 3 turned down in the center, and 4 on each side. When the heads are uneven in size 8 to 13 heads are packed in the crate.

Tiebout suggests a crate with heads 7 by 14 by ⅜ inches with ten pieces of 3 or 3½ by 22 by ¼ inches. This crate holds only six large heads. The standard California crate is 13 by 18 by 21⅞ inches and the pony crate is 8½ by 18 by 23½ inches inside.

The heads are packed in the crates in such a way that there is little shifting. In Southern California the heads are often packed two layers in a crate with the base at the top and bottom and the curds facing the center, usually 24 heads to the crate. When the pony crate is used there is only one layer of heads to the crate.

Storing.—Cauliflower is not ordinarily stored, but good sound heads can be kept for a short period in cold storage. Shipments from California reach the eastern markets in good condition after a period of two or more weeks in transit in refrigerator cars. If freshly cut heads were put in cold storage it should be possible to keep them for several weeks.

BROCCOLI

Broccoli is a large-growing, long-season, cauliflower, little grown in this country, but in recent years it has been given some attention in Oregon. The plant requires a full season in which to mature and is inferior to the cauliflower in quality hence it has not been regarded as satisfactory for commercial purposes in most sections of the United States. It is not a sure crop. The cultural practices for broccoli are about the same as for cauliflower except that more space and a longer growing season are required.

BRUSSELS SPROUTS

The edible portions of Brussels sprouts are the buds, or small heads which grow in the axils of the leaves (Fig. 23). The heads, 1 to 2 inches in diameter, are used in the same manner as cabbage and are also pickled.

This crop has been grown in the vicinity of Brussels, Belgium (from which place it gets its name) for hundreds of years. It has not become

an important crop in the United States. The most important producing section is in Suffolk County, New York.

Culture.—The general cultural requirements for Brussels sprouts are about the same as for cauliflower. The plant will stand considerable freezing and may be left out of doors until very severe freezing is expected. On Long Island the plants for the early crop are set out during the latter part of June and early July and for the late crop from July 20 to August 15. The plants are spaced 2 to 3 feet apart in the row with the rows 3 feet apart.

FIG. 23.—Plant of Brussel sprouts showing a large number of partially developed heads on the stem.

The fertilizer application for Brussels sprouts is about the same as for cauliflower, a ton or more to the acre of 4–8–4, 5–7–5, or 6–8–5 mixture. Manure is used by some growers and in the absence of manure some cover crop is turned under to supply humus. On Long Island rye is the principal cover crop, and for the early crop, the rye is allowed to grow 8 to 10 inches high before being turned under. The late crop sometimes follows early potatoes, but in this case a cover crop is usually plowed under for the potato crop.

Harvesting.—Harvesting begins usually in three to three and a half months after setting the plants. Early sprouts should be picked over several times, the lowest sprouts on the plant being taken each time, otherwise these will open out and become yellow. The first picking should not be delayed after the lower leaves begin to turn yellow as the sprouts

get tough and lose their delicate flavor. In picking the leaf below the sprout is broken off and the sprout removed by breaking away from the stalk. As the lower leaves and sprouts are removed the plant continues to push out new leaves at the top and in the axil of each leaf a bud or sprout is formed. The sprouts are placed in baskets or other containers as picked and carried or hauled to the packing house where they are placed in quart berry boxes. These boxes are packed in the ordinary 32-quart berry crate for shipment.

As freezing weather sets in the plants are pulled up or cut off near the surface of the ground and hauled to a shed or to some convenient place near the packing shed and stacked. A sheltered place, if available, is selected for stacking. The plants are stood upright on the ground as close together as possible and a light covering of marsh hay, seaweed, or other material is placed over them. Only a light covering is necessary since freezing does not injure the sprouts if they are thawed gradually, but alternate freezing and thawing spoils them. The stacks are only one layer deep.

After the plants are stacked the sprouts may be picked at any time through the winter. The leaves are stripped from the plants before they are brought into the packing house and the sprouts are removed with a small knife. After removal of the sprouts they are stripped of the outer, yellow leaves and placed in berry boxes.

For home use Brussels sprouts can be stored in a cool cellar, where they may be kept for a large part of the winter if the conditions are favorable. In mild climates the plants may be left in the field or garden throughout the winter.

KOHL-RABI

Kohl-rabi is grown for the turnip-like enlargement of the stem above ground (Fig. 24). It is little known and is not appreciated in the United States, although it is an excellent vegetable if used before it becomes tough and stringy. For good quality the growth must be rapid and there should be no check. The plants may be started in the greenhouse or hotbed for an early crop but the more common practice is to plant the seed where the crop is to mature.

Culture.—The seed is sown in rows 18 inches apart for hand cultivation or 24 to 30 inches for horse cultivation. The plants are thinned to stand 8 to 12 inches apart in the row. Four to 5 pounds of seed will plant an acre. Planting at intervals of 2 to 3 weeks will secure the proper sequence and insure a continuous supply of tender kohl-rabi.

A rich garden soil will produce excellent kohl-rabi. If the soil is not already rich a liberal dressing of manure is desirable. If manure is not available green-manure crops and commercial fertilizer may be used as substitutes. A high-grade fertilizer (4-8-4 or 5-10-5) at the rate

of 1,000 to 1,500 pounds to the acre in conjunction with soil-improving crops should give good results.

Cultivation similar to that given cabbage or cauliflower is satisfactory for kohl-rabi, but when planted in rows less than 24 inches apart hand cultivators are used.

Varieties.—The most popular varieties are White Vienna, Green Vienna, Purple Vienna and Earliest Erfurt. The White Vienna is probably grown to a greater extent than all of the others combined.

Fig. 24.—Kohl-rabi plant showing root, swollen stem and leaves. The edible portion is the turnip-shaped stem.

Harvesting.—Kohl-rabi should be harvested when the swollen stem is 2 to 3 inches in diameter and before it becomes tough and woody. When prepared for market the root is cut off and the plants are tied together in bunches like beets, or sold in bulk.

CHINESE CABBAGE

Chinese cabbage is little grown in the United States and is considered a new vegetable although it has been known by authorities in this country for many years. It is grown as a potherb and also as a salad plant. It requires a rich soil, abundance of moisture and a cool season. Quick, continuous growth is important, for a serious check in growth hastens the development of the flower stalk.

This plant is probably a native of China where it has been in cultivation since the fifth century.

Chinese cabbage (*Brassica pekinensis*) is not a true cabbage since it belongs to a different species. It is an annual and has very few characteristics of the true cabbage. Some types, or varieties, resemble chard and others resemble cos lettuce. Two distinct types are grown in the United States. One is a tall plant with a head 12 to 15 inches long and is often called Pe-Tsai while the other has a shorter and more compact head. The latter type is often called Wong Bok.

Culture.—Chinese cabbage thrives best during the cooler portion of the growing season, therefore, in the South it is grown as a winter crop, and in the other portions of the country as a fall crop. Hundreds of attempts have been made to produce Chinese cabbage as an early summer crop, but in most seasons the plants go to seed before forming a head.

When Chinese cabbage is started as a spring crop the seed is sown in a greenhouse or hotbed and the plants are handled about the same as cabbage. It is important, however, to prevent a check in growth, and, for this reason, the plants should not be allowed to get too large before setting out. It is best to set them in the field within 4 weeks of the time the seed is sown.

As a fall crop the seeds are often sown where the crop is to mature and after the plants become established they are thinned to stand 10 to 15 inches apart, depending upon the variety and the richness of the soil. Some growers prefer to grow the plants in an outdoor seed bed and to transplant the young plants to the field. If the plants are to be transplanted the work should be done while the plants are small.

Any rich soil which is retentive of moisture and in a good physical condition will produce a satisfactory crop of Chinese cabbage when the other conditions are favorable. Market gardeners select either a good loam or a sandy loam for this crop. A good muck soil is almost ideal for Chinese cabbage since this type of soil is rich in nitrogen and is retentive of moisture. The largest crops, seen by the author, were produced on mucks.

When grown on this soil a complete fertilizer high in potash is used, either a 2–8–10 or 4–8–10 mixture. For mineral soils a 5–10–5 fertilizer mixture will ordinarily give good results if used at the rate of 1,000 to 1,500 pounds to the acre. If the soil is not well supplied with humus manure should be applied, or a green-manure crop turned under prior to planting Chinese cabbage.

The general care of the crop is about the same as that given cauliflower, but the length of time required to grow a crop of Chinese cabbage is less than for cauliflower.

Varieties.—The Oriental Seed Company, San Francisco, California, lists and describes seven varieties of Chinese cabbage in the 1922 catalogue as follows:

Paoting (genuine "Wong Bok") big, compact, tender and crisp. We have found this to be absolutely the best firm-heading Chinese cabbage to grow during the summer months. It will not scald or burn. . . . It is excellent in quality, crisp, tender and brittle with a fine celery flavor. It will produce a head of 15 pounds and will stand long before going to seed.

Peking (genuine "Pe-Tsai") similar to the Chokurei in general appearance but is superior to it in every way. . . . The interior blanches creamy-white, crisp and delicious. . . . It produces successfully throughout the year and is considered one of the best fall and winter Pe-Tsai. It is a good keeper and shipper and its attractive appearance and fine quality make it one of the best sellers.

Chosen.—This is an old and popular standard variety with excellent flavor . . . . Grows up more like cos lettuce, with broad clumped leaves and is of easy maturity, tender and mild in cabbage flavor.

Shantung, a production of Shantung, a province of China. Distinctive flavor, very mild and pleasant. The outside leaves are large and round, the heart is snowy-white with compact leaves tightly held together.

Chokurei, a most excellent one among the varieties. Large outside leaves with a yellow striped color and the inside leaves grow round gradually, more like cos lettuce. The heart is pure white, tender, sweet and delicate in taste. The young leaves are very popular for use in salad. It is very hardy and will keep until early spring if placed in the cellar.

Kinshu.—This is our leading variety, the best and most popular grown, known for its quality and compact leaves which are held tightly together. The leaves have some wrinkles and grow more like head cabbage, a little shorter than the preceding variety and taller than Che-foo. The best, and easily self-blanching. The heart is snow-white, crisp and tender.

Che-foo.—One of the most excellent varieties. Large outside leaves with a dark greenish color and the inside is compact, tightly grown and has a beautiful white, crisp appearance with a mild cabbage flavor, delicate and delicious. It is naturally very hardy and productive and will stand against insects.

Harvesting.—Chinese cabbage is harvested when the heads are fully developed. The heads are cut from the stalk in the same manner as cabbage or cauliflower. The loose, outer leaves are removed as shown in Fig. 25, and the heads are packed in various ways. All kinds of packages are used since the crop has not become of sufficient importance to demand a special package. Some growers use flat baskets, others use boxes and crates of various kinds. Lettuce boxes are used to some extent and they are fairly satisfactory for the long-headed varieties. The heads are usually laid in the package rather than placing them upright, although the latter method has been used in packing in celery crates.

Chinese cabbage has been grown mainly for local markets, but the industry is developing at considerable distances from the consuming centers, therefore a good shipping package is needed.

Storage.—In China on the approach of winter the plants are pulled, the outer leaves are removed and the heads are stored in an outside cellar.

In the United States storage has not been practiced to any great extent, although successful attempts have been made to store in cold-storage warehouses. At Cleveland, Ohio, Chinese cabbage has been kept for two months in cold storage. Mrs. Fred Osborne, Ann Arbor, Michigan,

FIG. 25.—Heads of Chinese cabbage, with the outer leaves removed. (*Courtesy, U. S Department of Agriculture*).

stored a carload of Chinese cabbage in cold storage in Detroit during the fall of 1919. The heads were cut from the stalk and placed upright in celery crates. Some of the heads were wrapped in paper while others were not wrapped. Mrs. Osborne reported no difference in keeping between those wrapped and those not wrapped since they all kept in perfect condition for a month.

CHAPTER XXI

ROOT CROPS

Beet	Rutabaga
Carrot	Radish
Parsnip	Horse-radish
Salsify	Turnip-rooted Chervil
Scorzonera or Black Salsify	Skirret
Scolymus or Spanish Salsify	Celeriac
Turnip	

These root crops thrive best in a cool season and in a deep friable soil. When produced in the South they are grown during the winter. Those requiring only a short growing period do better in spring and fall than in midsummer. All of the root crops are hardy, therefore may be planted early in the spring in the North and may be left in the field or garden until late in the fall.

All of the root crops listed above have similar cultural requirements. When grown for market they are produced on an intensive scale and are cultivated mainly by hand. Seeds are nearly always sown where the crop is to mature, the only exception being the beet, seeds of which are sometimes sown in a greenhouse or hotbed for a very early crop.

While the root crops are not of as much commercial importance as many of our vegetables, some of them are grown in nearly all home gardens and in most market gardens. They are grown to some extent as truck crops to be shipped to distant markets, but not to as great extent as most of the other well-known vegetables.

BEET

The garden beet is one of the most important of the root crops, being grown in nearly all home gardens and in a large percentage of market gardens. The value of the commercial crop in 1919, as reported by the Bureau of the Census, was $1,016,507, but this does not indicate its importance. It is grown on such a small scale by many market gardeners that the crop is not reported. This is shown by the fact that only 7,197 farms in the United States are reported as having grown beets for sale in 1919. The average value per acre in 1919 was $193.

History and Taxonomy.—The garden beet is probably a native of Europe, and while it has been known since about the third century it is essentially a modern vegetable. The first appearance of the improved beet in Germany is recorded about 1558 and in England about 1576. It was mentioned by McMahon in 1806 as being grown in the gardens of America at that time, although it is not definitely known when it was first brought over.

The beet is a biennial of the Chenopodiaceae or goosefoot family. The garden beet, stock beet or mangel, sugar beet and chard belong to the same species, *Beta vulgaris*. The plant produces a thickened root and a rosette of leaves the first year; the second year it goes to seed. The flower stalk grows to a height of about 4 feet. The calyx continues to grow after flowering, becomes corky and completely covers the seeds. This forms what is commonly called the beet seed, but in reality is a fruit containing usually 2 to 6 seeds. The true seeds are small, kidney-shaped and brown in color. They retain their germinating power for 5 or 6 years.

Soil Preferences.—While beets are grown on nearly all types of soil, they thrive best on a fairly deep, friable loam, moist, but well drained. The crop is grown commercially on sandy loam soil more than on any other type. Such a soil is especially desirable for an early crop, where earliness is more important than large yields. Where large yields are most important, as in growing the crop for canning or for the fall and winter market, a deep rich alluvial soil such as a silt loam is considered very desirable. Muck soil is almost ideal for late beets since it is loose and moist. Heavy soils are not satisfactory since beets are likely to be unsymmetrical in form when grown on such soils. It requires less labor to care for a crop of beets on a loose friable soil than on a heavy compact soil.

The soil for beets, and all of the other root crops, should be thoroughly prepared and the surface should be loose and smooth. It is difficult to plant and care for a crop of beets on poorly prepared land. Good preparation is more essential for crops cultivated by hand than those cultivated by horse-drawn cultivators, since hand cultivators are light and not adapted to heavy work, or for work in rough cloddy soil. After thoroughly pulverizing the soil it is desirable to smooth the surface by the use of a meeker harrow or drag just before planting the seed.

Manures and Fertilizers.—Beets must make rapid and continuous growth to develop the highest quality, therefore, a good supply of available nitrogen, phosphorus and potash is necessary. On sandy and sandy loam soils manure is valuable to supply humus as well as fertilizing elements and on heavy soils it is of importance in improving the physical condition by making them more friable. It is best, however, to apply fresh manure to a crop preceding beets on account of the weed factor. Well-rotted

manure may be applied to the land without danger of introducing weed seeds. Under most conditions it is probably not economical to depend upon manure alone. Applications of 15 to 20 tons of manure, supplemented with commercial fertilizers, will produce large yields if conditions are favorable for beets. Results of 6 years' experiments at the Rhode Island Station on a silt loam soil (*Bull.* 188) show that 16 tons of manure and 1,000 pounds of a 4–7–6 fertilizer produced a considerably larger yield than 32 tons of manure. In both cases the manure was applied to a crop of cabbage which preceded the beets the same season. The plats treated with 16 tons of manure also had 1,500 pounds of a 4–10–2 fertilizer applied to the cabbage so that the comparison is between the residue from 32 tons of manure and of the 16 tons supplemented with the equivalent of 1,000 pounds of a 4–7–6 fertilizer. Extra nitrogen added to the regular fertilizer treatment greatly increased the yield, as did extra phosphorus. Extra potash gave only a slight increase over the "manure and fertilizer" treatment. See Chapter III for a complete record and discussions of these results.

When manure is not used it is necessary, on most soils, to use green-manure crops to maintain the humus supply and to apply commercial fertilizers to furnish the necessary chemical elements. The amount and kinds of fertilizer that should be applied depends upon the type of soil and its fertility. On an ordinary sandy loam soil an application of 1,000 to 1,500 pounds of a 4–8–4 fertilizer should give good results. On a silt loam or clay loam both the nitrogen and potash might be reduced. For a muck soil a fertilizer containing 2 per cent nitrogen, 8 per cent phosphoric acid and 8 to 10 per cent potash is suggested. This may be applied at the rate of 1,000 to 1,500 pounds to the acre. For late beets on a fairly rich soil, especially when manure is used in the rotation, many growers use only about 800 pounds of a good grade of fertilizer per acre and secure high yields.

Planting.—A large part of the beet crop is grown from seeds planted where the plants are to mature, but a few early beets are grown from plants started in a greenhouse or hotbed. In growing plants for transplanting the seed is sown several weeks prior to the time for outdoor planting. The plants may be allowed to grow in the seed bed until time to set them in the field or garden, or they may be transplanted to flats, spacing them about 1½ inches each way as described for celery. By growing plants as described it is possible to get beets large enough for market two to three weeks earlier than is possible by planting seed in the garden. The transplanting method is expensive and is justified only where high prices can be secured.

Seeds and well-hardened plants may be planted outdoors as soon as the danger of hard freezes is over since light frosts will not injure the plants. In the South the crop is planted during the winter, the time

depending upon the severity of the weather. Where hard freezes do not occur the seed may be sown any time during the winter. For a succession of young, tender beets several plantings should be made at intervals of two or three weeks apart. It is the practice of many to make a late sowing of some quick-maturing variety for fall and winter use rather than to plant a slow-maturing variety in late spring or early summer. By following this practice it is possible to grow some other crop on the land before time for planting beet seed for the late crop. A quick-maturing variety will reach edible size in 60 to 75 days.

Plants are set by hand and are spaced about 4 inches apart in rows 12 to 18 inches apart for hand cultivation. Seed is sown with seed drills in rows 12 to 18 inches apart and 4 to 6 pounds of seed are required to the acre. Since the so-called seeds are uneven in size and irregular in shape it is difficult to make an even distribution. By sifting the seeds through screens separating them into various sizes a fair distribution can be made. The seed is covered ¾ of an inch to 1½ inches in depth depending upon the kind of soil and the amount of moisture present. On light soils the covering should be deeper than on heavy soils, and when the soil is dry more covering is needed than when it is moist.

Thinning.—Thinning is necessary no matter how evenly the seed has been planted since each fruit contains more than one seed. The plants come up in clumps and all but one of these should be removed. Very often thinning is delayed until the beets are large enough to use when the larger ones are removed and the small ones left to develop. Those left to mature should be spaced 3 or 4 inches apart.

Cultivation.—Clean, shallow cultivation should be given as needed to keep down weeds and to maintain a soil mulch. The root system is not very large and the beet seems to respond to cultivation even where weeds are not a factor. (See Chapter X.) Most cultivation is done by hand, using wheel hoes with either knife attachments or the cultivator teeth, the former being better for killing weeds and the latter for forming a mulch. Some hand hoeing, or hand weeding is necessary to keep down weeds between the plants in the row.

Varieties.—Goff (56) in 1887 proposed the following simple classification of garden beets based on shape and color.

1. Root oblate or top-shaped;
   A. Root Red
   B. Root yellow
2. Root oval:
   A. Root red
   B. Root yellow
3. Root half-long:
   A. Root red
   B. Root yellow
4. Root concial:
   A. Root red
   B. Root yellow

The yellow beets are of very little importance at the present time and varieties of this color are seldom listed. Of the oblate or top-shaped

roots of a red color Early Blood Turnip, Eclipse, Egyptian and Bassano are varieties that are still grown.

The most popular varieties of early beets are Crosby's Egyptian and others of the Egyptian type, followed by Eclipse. Other early varieties grown to some extent are Early Model, Edmand's Early, Early Blood and Crimson Globe. The Detroit Dark Red is the most popular late variety, followed by Edmand's Blood Turnip. It is a common practice among growers in many regions to make a late planting of some early variety such as Egyptian and Eclipse, instead of planting varieties requiring a long growing season.

Leaf Spot.—Leaf spot (*Cercospora beticola*) is very widespread in the eastern and middle states. The spots are ashen gray, surrounded by a purple border. The spot often drops out and the leaf presents a shot-holed appearance. A large part of the green tissue of the leaves may be destroyed or the leaves may die, in which case they blacken and remain standing. As the leaves die new ones are formed thus elongating the crown.

Cleaning up the refuse after harvesting the crop and practicing rotation are beneficial. Thorough spraying with Bordeaux mixture affords some control but it is seldom practiced.

Beet Leaf-miner.—The larva is a white maggot, about one-third of an inch long, which burrows in the tissue of the leaves of beets, chard, spinach and lamb's-quarter. They feed on the tissues between the upper and lower layers of the leaf and often cause serious injury by rendering the foliage unfit for food and checking the growth of the plant. Infested leaves present a blistered appearance.

Since the larva lives within the tissue of the leaf it cannot be reached by poisons. Destruction of fallen leaves and other refuse by plowing immediately after harvesting the crop will aid in controlling this pest since it passes the winter under rubbish in the field. Destruction of lamb's-quarter is also advised. Planting crops early in the spring, or late in autumn, when the insect is not present is practiced in growing spinach where this insect is serious.

Webworms.—At least two species of webworms attack beets by eating the leaves. The eggs are deposited on the leaves and the larvae attack the foliage, either spinning small webs among the tender leaves or else feeding on the underside, protected by a small web or with no protection whatever.

Spraying with arsenate of lead will aid in controlling this insect if care is taken to cover the underside of the leaves.

Harvesting.—Beets for bunching are often harvested as soon as they attain a diameter of 1¼ to 1½ inches. Very often this is a thinning process, the larger ones being removed each time, thus allowing the small ones room to develop. After they reach 2 inches in diameter bunch beets

are not in great demand. The beets are pulled by hand and the injured or dead leaves are removed before being bunched. Four to six beets are tied together, with the tops on, and then they are washed to remove any soil adhering to them. When bunched beets are shipped considerable distances the tops are often cut back about half way and the bunches are packed in boxes, crates or baskets.

The late crop of beets is pulled by hand, or loosened by means of a plow. The tops are removed as soon as they are harvested and the beets are packed for shipment or put in storage. They are packed in boxes, crates, baskets or bags and no particular grading is done, although the very large roots, the small ones and those injured in any way are discarded.

Storing.—Beets are very often stored in out-door pits or banks and in common storage houses of the types described in Chapter XV. The best temperature for beets is near the freezing point, but they should not be allowed to freeze. The air in the storage house or cellar should be kept rather humid to prevent wilting and withering of the roots. Beets keep well in cold storage at a temperature of about 32 degrees F., and this type of storage is being used.

CARROT

The carrot (*Daucus carota*) is a very popular vegetable and is increasing in importance, due to the fact that its value in the diet is better understood than it was formerly. It is especially desirable for children and its use is advocated by doctors and dieticians.

The carrot is grown in most home gardens, and, on a small scale in a large percentage of market gardens. According to the Census Report 6,522 acres of carrots were grown for sale in 1919 and the value of the crop was $1,563,010, but this probably does not include all carrots grown for market. New York is credited with slightly over one-fourth of the total commercial acreage or 1,810 acres valued at $450,032, and is followed by Massachusetts with 658 acres valued at $178,269 and California with 580 acres valued at $120,342.

History and Taxonomy.—The carrot is a native of Europe, Asia and northern Africa and possibly North and South America. It was probably cultivated by the ancients, but was not a common food plant. It is now grown throughout the world, but is more appreciated in Europe than in America.

It is a biennial of the Umbelliferae or parsley family. The genus Daucus, to which the carrot belongs, contains about 60 species, some of which are native in North America. Very few of the species are cultivated. During the first year a thickened root and a whorl of leaves are formed and at the beginning of the second year the flower stalk starts from the crown and grows to the height of 2 to 3 feet.

Soil Preference.—The carrot, like the beet, thrives best in a deep, loose loamy soil. It is grown commercially on sandy loams, silt, silt loams and muck soils. For an early crop a sandy loam is preferred but for large yields silt, silt loam, or muck is preferred, the last mentioned being especially desirable because of its fine, loose texture.

The preparation of the soil for carrots, should be the same as for beets. A fine, smooth seed bed is even more important for carrots than for beets, since carrot seed is small and slow to germinate.

Manures and Fertilizers.—The discussion of manures and fertilizers for beets applies equally well to carrots except that no comparable experimental data are availabe for the latter. The carrot is considered by many gardeners to be especially "hard on the land" probably due to its heavy draft on the supply of potash. Muck soil truckers report smaller yields of celery and onions following carrots than following any other crop. This has not been proven experimentally but the belief is so general that there is probably some truth to it. Since muck soils are usually poor in potash and since carrots utilize large amounts of this element it is believed that a large application of a potash salt would eliminate the apparent injurious effects of carrots on the succeeding crop. However, other factors may be involved. A yield of 10 tons of carrots will remove about 100 pounds of potash, 32 pounds of nitrogen and 18 pounds of phosphoric acid. According to Hartwell (65) the carrot is low in its response to phosphorus and this would be expected from the small amount removed in the crop.

Planting.—The carrot is grown from seed planted where the crop is to mature. It is hardy and the seed may be planted in the North, as soon as hard freezes are over in the spring and in the fall or winter in the sections of the South where hard freezes do not occur. For a succession of tender roots, the same variety may be planted at intervals of two or three weeks, or by sowing early medium and late varieties at the same time. The last sowing of a quick-maturing variety may be made as late as two months before the average date of the first killing frost in autumn. The varieties requiring a long growing season, commonly called late, require from four to five months to mature. Since many consumers prefer small roots the practice of growing early, small-rooted varieties throughout the season is becoming popular, although the half-long varieties are more largely planted for sale for fall and winter use.

Two to three pounds of carrot seed are sown per acre when the crop is to be cultivated by hand, which is the common practice. The rows are spaced 12 to 18 inches apart and the seed is sown with a seed drill where a considerable quantity is planted. In the home garden the seed is sown by hand in a shallow trench made with the handle of a hoe or rake as described in Chapter IX. Carrot seed is covered ½ to ¾ inch in depth, the greater depth being on light dry soil.

Carrot seeds germinate slowly and it is desirable to sow enough radish seeds with them to mark the rows so that cultivation may begin soon after planting. The radish seed will germinate in a few days.

Thinning.—Carrots usually require thinning and this is an expensive and laborious task. As soon as the plants become well established they are thinned to stand 2 to 4 inches apart in the row. For small-growing varieties which are to be marketed as bunched carrots a space of 2 inches, or even less, between plants is sufficient and for the larger varieties grown for human consumption a space of 4 inches is ample. On muck soil less space is usually given since the soil is so loose that there is no danger of the roots becoming deformed due to crowding. In fact it is desirable to

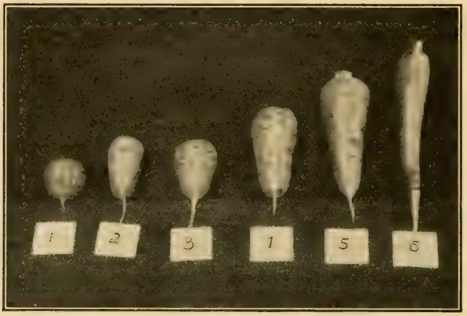

Fig. 26.—Six varieties of carrots representing the important types and varieties: 1. Paris Forcing; 2, Short Horn; 3, Oxheart; 4, Chantenay; 5, Danvers Half Long; 6, Long Orange.

have the plants stand rather thickly on a loose, rich soil to prevent the carrots from growing too large. Small to medium-sized roots are preferred to large ones. In the home garden, and to some extent in the market garden, the first thinning consists of removing surplus plants where they grow in clumps, leaving only one plant in a place. Later thinning is done when the larger roots are of sufficient size to be used. The larger ones are removed and the smaller ones left to develop.

Cultivation.—Cultivation to keep down weeds is very important, especially in the early stages of growth. Since the carrot grows very slowly for the first few weeks it cannot compete successfully with weeds. Shallow cultivation with hand cultivators is usually given and the knife attachments are used when there is considerable weed growth. Cultivation for the purpose of maintaining a soil mulch does not seem to be essential when weed growth is not a factor. This may be due to the fact that the carrot develops a large, and ramified root system as discussed in Chapter X.

Varieties.—Seedsmen list a large number of varieties of carrots but only a few of them are of any great importance. The most popular varieties are Chantenay, Danvers Half-long, Oxheart, Rubicon, Early Scarlet Horn, Half-long, Short Horn and Long Orange (Fig. 26). The Danvers Half-long and Chantenay are grown more than all others and are popular for both early and late planting. Goff (56) in 1887 made the following classification of varieties:

1. Root distinctly pointed.
   A. Root long—the length exceeding four times the diameter.
      (*a*) Root white
      (*b*) Root yellow
      (*c*) Root orange or red
      (*d*) Root purple
   B. Root half-long—the length not exceeding four times the diameter.
      (*a*) Root white
      (*b*) Root orange or red
2. Root distinctly premorse (blunt at lower end)
   A. Root long—the length exceeding four times the diameter
      (*a*) Root orange or red
   B. Root half-long—the length not exceeding four times the diameter.
      (*a*) Root orange or red
   C. Root very short—the length not exceeding twice the diameter.
      (*a*) Root orange or red.

Harvesting.—Carrots for bunching are often harvested as soon as the roots are $\frac{1}{2}$ to $\frac{3}{4}$ of an inch in diameter at the upper end. This may be a thinning process. When the entire crop is to be removed at one time and the roots are long a plow may be used to advantage by running it close to the row throwing the furrow away from the plants. The roots can then be pushed sideways and pulled with ease.

Early carrots are nearly always bunched in preparation for market. The tops are left on and 8 to 12 roots are tied in a bunch. They should be washed and carefully graded before being put on the market. When sold on local markets the bunches are usually loaded into wagons or trucks without containers, but when shipped they are packed in crates, boxes, baskets and hampers.

Late carrots are usually topped as harvested and are sold by measure or by weight. They are packed in various types of boxes, crates, baskets, hampers and barrels, and even in bags.

Storage.—Carrots are stored in the same manner as beets.

PARSNIP

The parsnip (*Pastinaca sativa*) is not a very important commercial crop, due largely to the fact that it requires a long growing season, so that no other crop can be grown on the land during the same season. On

high-priced market-gardening land growers produce two, three or more crops in a season. In addition to this the parsnip is not a popular vegetable with the consumer. According to the Census Report the value of the commercial crop in 1919 was $244,435 and the value of the product per acre was $289.

History and Taxonomy.—The parsnip is a native of Europe and Asia. The parsnip is found growing wild in America, but only as an introduced weed. The parsnip has been used as food from an early period, and was undoubtedly known to the ancient Greeks and Romans. It was brought to America by the early colonists and was in cultivation in Virginia as early as 1609 and in Massachusetts in 1629.

The plant is a biennial of the Umbelliferae or parsley family, but the crop is grown as an annual. The second year the seed stalk develops from the enlarged root produced during the preceding season.

Soil Preferences.—A deep, rich soil is essential for successful growing of this crop. On a shallow soil the roots become crooked, and, often branched. Heavy soils are objectionable because of the difficulty of securing a good stand of plants and smooth roots. Since the seeds are very slow to germinate the surface of a heavy soil becomes baked before the plants have a chance to break through, hence a poor stand usually results on such soils.

The methods of preparation of the soil for the parsnip are the same as for the beet.

Manures and Fertilizers.—The manure and fertilizer treatments suggested for beets should give satisfactory results for parsnips under similar conditions.

Planting.—Parsnip seed is planted where the crop is to mature and since the seed is slow to germinate and the crop requires a long growing season planting is usually done fairly early in the spring when the soil is moist. The seed retains its vitality only one or two years and should be planted thickly. It is usually sown in drills about 15 to 18 inches apart for hand cultivation and 24 to 30 inches for horse cultivation. One ounce of seed will plant about 200 feet of row and 4 to 6 pounds are usually planted to the acre when the rows are about 15 inches apart. The seed is covered ½ to ¾ of an inch deep. It is desirable to sow some radish seed with the parsnips so that cultivation can begin before the parsnip plants break through the surface of the soil.

After the plants are well established, in 5 or 6 weeks, they are usually thinned to stand 2 to 4 inches apart in the row. Some growers leave the plants as far as 6 inches apart in the row, but this distance is greater than is necessary under most conditions.

Cultivation.—Cultivation should begin as soon as weed growth starts, or as soon as a crust begins to form. It can begin in a few days after planting if radish seed has been sown with the parsnip seed. It is

important to keep down weed growth by cultivating and weeding until the plants are large enough to smother the weeds in the row. During the early stages of growth parsnip plants are delicate and cannot compete successfully with weeds, but after they cover the ground they can take care of themselves.

Hand cultivation is commonly given and the knife attachments are used to a considerable extent, especially when the parsnip plants are small. The Barker weeder or mulcher is also used to some extent and this is very satisfactory on light soil, if employed while the weeds are very small. This implement destroys the weeds and leaves a fine mulch of soil on the surface.

Varieties.—Very few varieties of parsnips are listed by American seedsmen and two of these, Hollow Crown and Guernsey are used by a large percentage of growers. Long Dutch, Model and Offenham Market are grown to some extent.

Harvesting.—Parsnips are usually left in the ground until late in the fall, or even throughout the winter, since freezing is considered to improve their flavor. In many sections they are left in the garden until wanted for use, but where severe freezing occurs this is not satisfactory because it is difficult to dig them when the ground is frozen. The common practice in the North is, therefore, to harvest the roots late in the fall and store them where they are available when wanted. Since the parsnip root grows to considerable length, 10 to 12 inches, it is difficult and expensive to dig them. They may be dug by hand with a spading fork or they may be loosened with a plow. When a plow is used it is best to run it close to the row and throw the furrow away from the plants and then loosen the roots by pushing them toward the furrow. Care must be taken to prevent breaking the roots.

After digging, the tops are usually removed and if the parsnips are to be marketed immediately they should be washed. The roots are packed in various types of packages, including baskets, hampers, crates and boxes.

Occasionally young, tender parsnips are harvested and sold in bunches with the tops on as described for carrots and beets. Four to six specimens are put in a bunch. This practice is more common in Europe than in America.

Storage.—The same methods of storage are used for parsnips as for beets and carrots. A large part of the crop is sold during the winter and early spring, hence storage is important in regions where the soil remains frozen during most of the winter.

SALSIFY

Salsify (*Tragapogon porrifolius*) also known as "vegetable oyster," because of its flavor, is of very minor importance in this country, but is deserving of greater use. It is a native of southern Europe and is of

recent culture, probably not being grown as a food plant until about 1600. It is a hardy biennial belonging to the Compositae or sunflower family. The leaves are very narrow resembling those of the leek but smaller.

Culture.—Salsify requires a long growing season for full development and the culture of the crop is practically the same as that given parsnips. The seeds are sown in drills 12 to 15 inches apart and the plants thinned to stand about two inches apart in the row.

As salsify is hardy it can be harvested throughout the winter in most regions, but in order to secure a continuous supply for use or for market it is desirable to store a part of the crop. It may be stored as described for beets.

The roots are prepared for market by cutting away all but 2 or 3 inches of the leaves, washing the roots and tying 10 to 12, or more plants in a bunch. The bunch is usually tied tightly near both ends.

SCORZONERA OR BLACK SALSIFY

Scorzonera (*S. hispanica* Linn.) also known as Black Salsify, is a perennial, native of central and southern Europe. It belongs to the Compositae family and is grown in the same manner as salsify, except that it is given more room. The roots are long and black and are boiled after being soaked in water to remove the bitter taste.

This plant was known in Spain about the middle of the sixteenth century for its medicinal properties. It is grown in Europe as a food plant but is practically unknown in America.

SCOLYMUS

Scolymus or Spanish Oyster plant (*Scolymus hispanica* Linn.) is also a native of Europe and a member of the Compositae family. It is grown and used in the same way as salsify. The root is longer and produces a larger yield. When cooked its flavor is less pronounced than that of salsify, but it has an agreeable flavor and is worthy of attention in this country. It can be dug and stored in the fall or harvested as needed during the winter and spring. The leaves of this plant are prickly and somewhat unpleasant to handle on this account.

TURNIP

The turnip (*Brassica rapa*) is not of great commercial importance, but is grown by a large percentage of home gardeners. The value of the crop grown for sale in 1919, according to the Census Report, was $543,071 and this was produced on 4,056 acres. Three states, New York, New Jersey and Massachusetts, produced over one-fourth of this acreage.

The turnip is a cool-season crop, being grown mainly in the fall in the northern states and during the winter in the South. In the latter section it is grown mainly for the tops which are used as greens.

History and Taxonomy.—It is not definitely known where the turnip originated, but it is said to be found growing wild in Russia and Siberia. It has been in cultivation since ancient times and was brought to America at an early period. It was known in Virginia in 1609.

When planted in the spring the turnip is an annual, but when planted later it is a biennial. It belongs to the genus Brassica and the family Cruciferae, and is therefore closely related to the cabbage, cauliflower, rape, kale, etc.

Soil Preferences.—While the turnip is grown on all types of soil it thrives best on a deep rich loam.

The method of preparation suggested for beets and carrots would be satisfactory for turnips. In fact the turnip is not nearly so exacting in this respect as either beets or carrots since the seeds germinate quickly and the plants make rapid growth.

Manures and Fertilizers.—The manure and fertilizer treatments suggested for beets would be satisfactory for turnips, although beets are usually more heavily fertilized. Turnips do not seem to need as much potash as most of the other root crops, but require as much phosphorus and nitrogen. Since it is grown very largely as a fall crop, following some other vegetable, the manure and fertilizer applied to the first crop is depended upon to furnish sufficient mineral nutrients for the turnip. In some cases additional fertilizer, especially some nitrogenous material is applied. If the land has been heavily manured and fertilized for the first crop no additional treatment is needed, but under most conditions an application of 500 to 750 pounds per acre of a good fertilizer would be justified.

Planting.—The turnip is grown almost entirely from seed sown where the crop is to mature. Since it does not thrive in hot weather the seed is planted very early in the spring and in late summer in the North, and during the fall and winter in the South. For the fall crop in the North the seed should be planted about two months before hard freezes are expected. Seed for the spring crop should be planted as soon as the soil can be prepared.

Turnip seed is generally planted in rows 12 to 15 inches apart for hand cultivation and about 24 inches apart for horse cultivation. Seed drills are used where a considerable area is to be planted and the seed is covered about $\frac{1}{2}$ inch deep. The usual rate of planting is 2 pounds of seed to the acre for hand cultivation and a little less for horse cultivation. Broadcast seeding is not practiced to the extent that it was formerly, but when this method is followed more seed is required than under the row method. A comparison of drill and broadcast sowing of seed was made at the Wyoming Experiment Station and the results were decidedly in favor of planting in rows. Twelve varieties were used in the experiment and the average yield was 60,578.8 pounds for the

drilled and 28,429 pounds for broadcast planting. The rows were 30 inches apart and where the seed was sown broadcast it covered a strip 1 foot wide. (See Wyoming *Bull.* 22, 1894.)

Thinning.—After the plants become well established they are thinned to stand 2 to 6 inches apart in the row, the distance depending upon the type and the purpose for which the crop is grown. If small-growing varieties are grown for bunching the smaller distance is sufficient while the large varieties require the greater distance, if they are to develop to large size. In the South the thinning continues over a considerable period and the plants removed are used as greens.

Cultivation.—Cultivation is usually given turnips when they are grown in rows, but when the seed is sown broadcast cultivation is impossible. The methods of cultivation suggested for beets is satisfactory for turnips.

Varieties.—Turnips may be separated into groups based on shape and color. Goff (56) in 1887 suggested the following classification:

1. Root distinctly conical, or cylindrical.
   A. Root white, at least in the lower part.
   B. Root yellow, at least in the lower part.
   C. Root grayish, brown or black, at least in the lower part.
2. Root more or less distinctly oval. (Ovoid)
   A. Root white, at least in the lower part.
   B. Root yellow, at least in the part below ground.
3. Root spherical, or top-shaped.
   A. Root white, at least in the lower part.
   B. Root yellow, at least in the lower part.
4. Root distinctly flattened. (Oblate)
   A. Root white, at least below.
   B. Root yellow, at least below.
   C. Root grayish, brown or black.

The most popular varieties are the Purple Top Globe, White Milan, White Flat Dutch, White Egg, Yellow Globe and Yellow Aberdeen. The Seven-top is a popular variety in the South where the foliage is used for greens.

Diseases and Insects.—Most of the diseases and insects affecting the turnip are also injurious to cabbage and have been discussed under the latter. Club-root and black-rot are the most serious diseases and turnip aphis, root maggot and flea beetles are the most injurious insect pests.

Harvesting.—Turnips are harvested in the same manner as beets. When used as greens the plants are thinned and the foliage is cooked in the same way as kale. Young turnips are often bunched as described for beets, but a large part of the crop is harvested in the fall and the tops

are cut off as they are pulled. The turnips are then packed for market, or are stored. The methods of storage are the same as for the other root crops.

RUTABAGA

The rutabaga (*Brassica Napobrassica*) is similar in general appearance to the turnip, but differs from it in having a denser root, which is usually rounded or elongated instead of being flattened; the leaves are smooth and covered with a bluish bloom whereas the leaves of turnip are hairy and green. The roots arise from the underside of the enlarged root as well as from the tap-root in the rutabaga and the crown is long and leafy as compared to the turnip.

The culture is practically the same as that given the turnip, except that it requires 4 to 6 weeks longer to mature and grows to greater size than most varieties of turnips.

RADISH

The radish is a favorite crop of the home gardener because it is easily grown and is ready for use in 3 to 6 weeks from time of seed sowing. As a commercial crop it is grown to a limited extent by a large percentage of market gardeners, by many greenhouse vegetable growers and by truck growers in a few localities, especially in Mississippi and a few other southern states. It is not a crop of great commercial importance, the Census Report showing only 2,014 acres produced for sale in the United States in 1919. Mississippi and California produced over one-fourth of the acreage. The value was $437,286 and the average value per acre was $217.

The radish is probably a native of Europe and Asia. It has been in cultivation for a very long time, being highly prized by the Egyptians at the time of the Pharaohs, and was also known and highly prized by the ancient Greeks.

The radish (*Raphanus sativus* Linn.) is both annual and biennial, and belongs to the Cruciferae or mustard family. It is related to the cabbage, mustard, etc., but does not belong to the same genus.

Soil Preferences.—The radish is grown on all types of soils, but a light, friable soil is considered best. Since it requires only a short time to grow a crop of the varieties commonly grown in America it can be produced on types of soil that are not satisfactory for other root crops. For an early crop sandy, or sandy loam soils are preferred but for summer radishes a cool, moist soil gives better results.

The preparation of the soil should be about the same as described for beets and other root crops.

Manures and Fertilizers.—Since this crop is grown largely in early spring, or in winter some readily available fertilizer should be used. In

addition to commercial fertilizer well-rotted manure is often used in large quantities, but fresh manure should never be used immediately before planting. On any good garden soil 800 to 1,000 pounds of a 5–10–5 fertilizer should produce good yields of radishes. Very often the fertilizer is applied for the main crop, using sufficient quantity to supply the radish grown as a companion crop.

Planting.—The radish is hardy and the first planting is therefore made very early in the spring in the North and during the winter in the South. For a succession of crisp, tender roots several plantings should be made at intervals of about 10 days. By the proper selection of varieties radishes may be had throughout the season and even during the winter since the winter varieties can be kept in storage. However, most of the radishes grown in this country are the quick-maturing varieties, which do not thrive well in hot weather.

It is very often grown as an intercrop or companion crop and is planted between the rows of other vegetables, so that the spacing is determined to a considerable extent by the distance allowed the other crop or crops. When planted alone the rows are spaced about 12 to 15 inches apart requiring 10 to 12 pounds of seed to the acre. The seed is sown by hand for small plantings in the home garden and with seed drills in commercial gardens. It is sown rather thickly and the plants thinned after they become established. The first thinning leaves the plants ½ to 1 inch apart for the small varieties and then the larger ones are pulled as soon as they reach edible size. Large-growing varieties, especially those known as "winter radishes" are thinned to stand 2 to 4 inches apart in the row.

Experiments have shown an advantage in earliness and yield from the use of large seed and many writers recommend the sifting out of the small, poorly-developed seed. This is undoubtedly a good practice with much of the commercial seed, although it is not generally practiced. Eliminating the small seed would result in a more nearly uniform stand and save labor in thinning.

Varieties.—Varieties of radishes are divided into classes with reference to the season of the year in which the crop is grown, and with reference to the shape of the root. The former system has the advantage of bringing together those varieties which are planted at the same time, but it does not aid in identifying them. Goff (56) suggested the following classification based on the form of the root:

1. Root oblate, spherical or top-shaped.
   A. Root white.
   B. Root yellow, light brown or grayish.
   C. Root red.
   D. Root purple.
   E. Root black.

2. Root more or less distinctly oval: (ovoid).
   A. Root white.
   B. Root grayish.
   C. Root red.
   D. Root purple.
3. Root conical or cylindri-conical.

This class has all of the color divisions of Class 2 and an additional one—root black.

Another method of classification based on form is commonly used. This is as follows:

1. Root flat or oblate.
2. Root globular.
3. Root olive-shaped.
4. Root half-long.
5. Root long.

These classes have the various color divisions.

For practical purposes grouping of varieties with reference to the season of year in which the crop is grown is the most satisfactory method. They are classed as spring, summer and winter varieties. The most popular globular roots are Scarlet Turnip, Scarlet Turnip White Tipped, Scarlet Globe, Rapid Red and White Box; the best known olive-shaped spring radishes are French Breakfast and Ne Plus Ultra. The long-rooted spring varieties are represented by Cincinnati Market, Icicle or White Icicle, Long Scarlet Short Top and Chartier. Of the summer varieties Strasburg, White Vienna, Golden Globe, Stuttgart and Chartier are well known. All of these except the Golden Globe have long roots. Among the winter varieties are White Chinese, China Rose, Long Black Spanish, Round Black Spanish and Sakurajima. The Sakurajima grows to enormous size and has solid, firm flesh of good flavor.

Insects.—The insects most commonly attacking radish are plant lice, cabbage root-maggot and flea beetles. Plant lice can be controlled by spraying with one of the tobacco sprays, to which soap has been added as a sticker. Dusting with nicotine dust as described for the cabbage aphis would probably be effective. The maggot can be kept in check by screening the bed, but this is impracticable except on a very small scale. Corrosive sublimate solution applied in a stream along the row also aids in keeping the maggot under control. Two applications should be sufficient. Keeping the plants covered with Bordeaux mixture will protect them against the flea beetle, but the treatment stunts the plants, therefore is not practicable.

Harvesting and Marketing.—Harvesting usually begins as soon as the roots reach edible size. The quick-maturing, spring varieties become strong and pithy if not harvested soon after they reach edible size.

The summer varieties remain edible much longer than the spring varieties. The winter varieties remain edible for several months if stored properly.

Radishes are usually pulled by hand and are tied in bunches of 6 to 12 for the smaller-growing varieties and 3 to 6 for the larger varieties. After bunching they are usually washed to remove the soil and to give them a fresh, bright appearance. When shipped to distant markets the bunches are packed in baskets, hampers or barrels. For long distance shipping, ice is usually put in the package as described for spinach. Winter radishes are handled in much the same way as turnips, the tops being removed before the roots are put in storage.

HORSE-RADISH

Horse-radish (*Armoracia rusticana*) is found in many farm gardens where it is allowed to grow along the fences or walks. Commercially it is grown principally in Missouri (in the vicinity of St. Louis), Illinois, New York and New Jersey. Missouri produced over one-third of the commercial product in 1919. The total value of the commercial product in 1919, according to the Census Report, was $205,767 and was produced on 922 acres. The value of the product per acre was $223.

Horse-radish is indigenous to eastern Europe and is now spontaneous in the United States. Both leaves and roots were used as food in Germany during the middle ages. It was probably grown for medicinal purposes only prior to the 16th century.

It belongs to the Cruciferae or mustard family and is known as *Armoracia rusticana* and *Cochlearia armoracia.* It is a hardy perennial which produces a tuft of large leaves similar in appearance to the leaves of dock. The flower stem grows to a height of 2 to 3 feet and bears small white flowers in panicled racemes. Seed is produced but it seldom matures and is never used for propagation.

Soil.—A deep, rich, moist, loamy soil is desired for growing horse-radish. On hard soil the roots become much branched and crooked. In the vicinity of St. Louis a rich river-bottom soil is used for growing this crop.

In the preparation of the soil it should be deeply plowed and thoroughly pulverized so that long straight roots can be grown.

Manures and Fertilizers.—Unless the soil is already rich and in good physical condition it should be heavily manured, preferably with well-rotted manure. Some commercial fertilizer, is often applied in addition to a heavy coating of manure, but the manure supplies enough nitrogen and potassium, but phosphorus should be added. An application of 500 to 750 pounds of acid phosphate to the acre should be sufficient. Where manure is not used a ton of high-grade fertilizer per acre is none too much on a sandy loam soil. On such a soil a 5–10–5 mixture should give good results, provided the soil is well-supplied with humus.

Planting.—The plant is propagated from root cuttings made from the side roots which are trimmed off in preparing the roots for market. These vary in size from ¼ to ½ inch in diameter and from 2 to 8 inches in length. The long cuttings are best. As these roots are nearly uniform in diameter throughout their length, they are cut off square at the top and oblique at the lower end to denote which end is to be planted up. They are then tied in bundles, packed in sand and stored in a cool, moist place until spring. The cuttings may be planted in a deep furrow made with a large plow, or a dibble may be used to make holes to receive them. In either case the cuttings are set in a slanting position with the square end up and about 3 or 4 inches below the surface of the soil. The soil should be well packed around the cuttings. The distance of planting is about 10 to 15 inches apart in the row with the rows 3 to 4 feet apart. Planting is usually done early in the spring so as to give the crop a full growing season.

Cultivation and Care.—The crop makes most rapid growth during the latter part of the summer, therefore, thorough cultivation should be given throughout the growing season.

In order to secure large, straight roots some growers remove the side roots early in the season. This is done by removing the soil and stripping off the side roots from the upper part of the main root. The soil is then replaced. This treatment results in the production of large, compact roots, but unless the work is carefully done serious injury may follow. The earlier in the season the trimming is done the less check there is to growth. It is claimed by some that a larger yield is secured when the roots are trimmed than when they are allowed to grow without being disturbed. Certainly trimming results in a large percentage of straight roots of good size.

Harvesting.—The roots are hardy and may be left in the ground all winter, but it is better to dig them in the fall and store them so that they will be available when wanted. The roots are plowed out, the tops and side roots removed and the marketable product sold, or stored. Since the horee-radish is likely to become a bad weed it is important to remove all of the roots, in harvesting. The roots are washed and packed in barrels for shipping to market. For special trade they are sometimes tied in bunches of 6 or 8 roots. Only the large, straight roots bring a good price on the market.

The roots are stored in a cool, moist cellar or storage house. Care must be taken to prevent the roots from becoming withered.

TURNIP-ROOTED CHERVIL

Turnip-rooted chervil (*Chaerophyllum bulbosum* Linn.) is a small-rooted plant, native of Europe and Asia. It is a biennial, belonging to the Umbelliferae family and is of recent culture. The root is swollen,

much like a short carrot but smaller, dark gray in color with yellowish-white flesh.

In Europe the seed is usually sown in autumn since it does not germinate well if kept over winter in the ordinary manner. Spring planting may be followed if care is taken to stratify the seed in sand. If this is done the seeds germinate immediately after they are sown. The crop gets its growth in a relatively short time, but it improves in quality if left in the ground after the leaves wither and die. The roots may be taken up and stored if the land is needed for another crop. They keep well through the winter if properly stored.

The roots are eaten boiled and they have a sweet, aromatic flavor. This plant is little known in America.

SKIRRET

Skirret (*Sium Sisarum* Linn.) is a hardy perennial of the Umbelliferae family, although it is grown as an annual. The plant produces numerous swollen roots, forming a bunch from the crown. The roots are grayish-white in color with firm white flesh.

It may be propagated from seeds, offsets, or division of the roots. The seed is often sown in a prepared bed and the seedlings transplanted to the permanent bed when four or five leaves have developed. Plants propagated from offsets, and division of the roots are treated like those raised from seed. Skirret is very hardy and the roots may be left in the ground throughout the winter.

The roots are tender and have a sweet taste. They are used in the same manner as salsify.

CELERIAC

Celeriac or turnip-rooted celery (*Apium graveolens* Linn. var *rapaceum* DC.) is grown for its thick, tuberous base, which is used as a salad or as a cooked vegetable. It has the flavor of celery and is popular in Europe but is little grown in America. The plant does not develop as much foliage as celery.

Seed is usually sown in a greenhouse or hotbed for an early crop and in a well-prepared outdoor bed for a late crop. The plants are handled exactly like celery except that they are not blanched since the leaves are not eaten. European seedsmen list several varieties of celeriac. Giant Prague, Apple and Early Paris probably are the most popular. In America the Giant Prague is the most common and many seedsmen list no other variety.

CHAPTER XXII

BULB CROPS

ONION	SHALLOT
LEEK	CIBOUL (CIBOULE) OR WELCH ONION
GARLIC	CHIVE

All of the bulb crops are hardy and thrive best in relatively cool growing seasons. When grown in the South they are usually planted in fall, or winter and harvested in spring, or early summer. The onion is the only member of this group grown to any great extent in this country. The other crops are grown chiefly for sale in large cities where there is a considerable foreign population, since they are not relished by Americans.

All of these crops belong to the same genus, Allium, of the family Lilaceae, and their cultural requirements are very similar.

ONION

The onion is by far the most important of the bulb crops and is exceeded in value only by potatoes, sweet potatoes, tomatoes and cabbage of the vegetable crops grown in the United States. In 1919 the value of the commercial crop of dry onions in the United States was $21,387,221. Nearly two-thirds of the crop was produced in 6 states as shown in Table XXX.

TABLE XXX.—ACREAGE AND VALUE OF ONIONS IN THE SIX LARGEST PRODUCING STATES IN 1919

State	Acreage	Value
California	8,512	$2,818,194
New York	7,500	2,804,153
Texas	6,253	2,654,047
Massachusetts	4,411	2,299,939
Ohio	5,713	2,134,346
Indiana	4,191	1,067,866

In addition to the dry bulb crop thousands of gardeners produce small quantities of green onions for bunching. These are grown on such

a small scale by most producers that they are not included in the census report.

History and Taxonomy.—The onion is probably a native of Asia, perhaps from Palestine to India. It has been in cultivation and used as a food from the earliest period of history. It is mentioned in the Bible as one of the things for which the Israelites longed in the wilderness. It is mentioned as being cultivated in America as early as 1629.

The onion belongs to the genus Allium which contains about 300 species widely distributed in northern temperate regions, biennials and perennials, mostly bulbous. Many species are native to North America. Some of the wild species produce bulbels instead of seed in the flower cluster, as does the tree onion. All but a few of the plants of this genus have the characteristic onion odor and flavor.

Soil Preferences.—Onions are grown on nearly all types of soils from the sandy loams and mucks to heavy clays. The clays are not satisfactory unless well supplied with humus to lighten them. The greatest difficulty encountered in growing onions on clay is the tendency of this type of soil to run together and bake after hard rains. This is especially injurious after the seed has been sown and before the plants have attained sufficient size to permit of cultivation. Sandy loam soils, when well supplied with humus and heavily fertilized, are satisfactory for onion growing, especially for the early crop. Silty and silty loam soils are used in growing Bermuda onions in Texas and the common onion in Massachusetts. These are rich, river bottom soils and are quite satisfactory, especially when there is a considerable amount of sand present. Muck soils are considered the very best type for the production of bulb onions in the North. A very large part of the dry bulb crop grown in New York, Ohio, Indiana, Michigan and California is produced on muck. Muck soils are almost ideal in texture so that they are easily prepared and cultivated. They are organic in nature, rich in nitrogen and have a high water-holding capacity.

Soils for onion production should be thoroughly prepared. The seed bed should be thoroughly pulverized and have a smooth surface. It is a common practice to drag or roll the land just prior to planting and this is especially important for muck soils.

Manures and Fertilizers.—Manure is important in growing onions on mineral soils, especially those poor in humus, but on muck soils the humus is not necessary and nitrogen, phosphorus and potash can be supplied more economically in chemical fertilizers. Where manure is used it is advisable to apply it to the crop preceding onions, especially if it is not well rotted. Fresh manure usually contains weed seeds, and, unless plowed under, it interferes with planting and cultivating. Even where manure is used on mineral soils it is desirable to apply some commercial fertilizer, especially phosphorus. Some readily available nitro-

gen is also desirable to give the crop a start before the nitrogen in the manure or in the soil becomes available. When manure is used an application of 15 to 20 tons per acre should be sufficient. Fresh manure, if used, should be turned under in the fall or as early in the spring as possible. Well-rotted manure might be applied to the surface after the land is plowed but before it is disked and harrowed. In addition to the manure, an application of 500 pounds of acid phosphate and 100 to 150 pounds of nitrate of soda per acre is desirable on most mineral soils. Where manure is not used a complete fertilizer, containing 2 to 4 per cent nitrogen, 8 per cent phosphoric acid and 4 per cent potash applied at the rate of 1,000 to 1,500 pounds to the acre is recommended. Of course, the formula and amount should be varied according to the soil needs. In the Connecticut Valley of Massachusetts growers apply about 3,000 pounds of high-grade fertilizer to the acre. This is a very heavy application and it is doubtful if the crop can utilize it.

On a good type of muck soil, potash is the main limiting element and many onion growers use nothing but 200 to 400 pounds per acre of muriate or sulphate of potash. Phosphorus, however, usually increases the yield and improves the keeping quality. Nitrogen usually does not give sufficient increase to pay for the cost, and in some instances, it actually decreases the yield of marketable onions. This is especially true with a slowly available form of nitrogen, which stimulates foliage growth late in the season when the bulbs should be maturing. Connor and Abbot (28) give results of eight experiments with onions on muck soil in Indiana, which indicate the great importance of potash. A basic fertilizer containing 4 per cent nitrogen from dried blood, 8 per cent phosphoric acid from acid phosphate and 10 per cent potash from sulphate of potash was applied at the rate of 1,000 pounds per acre. The soils were fairly productive as is shown by the average yield of 404.4 bushels of onions per acre on the unfertilized plats. It is stated that this productiveness in most cases, was due to previous treatments, but in some instances the soil was virgin. The average yields of onions in bushels per acre were 404.4 for the unfertilized plats, 534.7 on the plats receiving a 4–8–10 mixture, 527.2 on the 0–8–10 plats, 488.4 on the 4–0–10 plats and 453.4 on the plats fertilized with a 4–8–0 mixture. The 4 per cent nitrogen increased the yield only 7.5 bushels per acre which was not enough to pay for the material. Phosphorus and potash increased the yield 122.8 bushels, nitrogen and potash 84 bushels and nitrogen and phosphorus 49 bushels over the unfertilized plats.

In a more elaborate experiment conducted by the U. S. Department of Agriculture in cooperation with the Indiana Experiment Station in Northern Indiana similar results were secured. The land on which this experiment was conducted had been in cultivation only 2 or 3 years and had grown nothing but corn, which was fertilized with 100 pounds of

muriate of potash per acre. Results for 3 years, 1915 to 1917 have been reported by Beattie (40). The results are given in Table XXXI.

TABLE XXXI.—SUMMARY OF ONION FERTILIZER EXPERIMENT AT NORTH LIBERTY, INDIANA, 1915, 1917

Kind of fertilizer	Amount per acre, lb.	Average yield per acre, bu.
Nitrate of soda	200	220.8
Tankage	200	
Acid phosphate, 14 per cent	457	365.3
Muriate of potash	200	467.9
Muriate of potash	400	449 9
Sulphate of potash	200	426.2
Manure	30,000	490.7
Limestone	2,000	377.4
Acid phosphate, 14 per cent	457	470.2
Muriate of potash	200	
Acid phosphate, 14 per cent	457	477.9
Muriate of potash	400	
None	....	356.7

The poor yields on the nitrogen plats are accounted for mainly by the fact that these were located on the edge of the area and suffered severely from wind injury. However, it was evident throughout that nitrogen was not needed. Attention is called to the fact that sulphate of potash did not give as good results as muriate. This difference is not significant in itself but similar results are shown in unpublished data from experiments carried on in New Jersey for 4 years and in New York for 2 years. The manure produced the highest yield, but the main difference was in the first year when the soil was quite new and in need of inoculation. (See Chapter III.)

From a study of experimental data it would seem that an application of 500 pounds of acid phosphate and 200 to 400 pounds of muriate of potash per acre is sufficient for onions on muck soil under normal conditions. A light application of nitrate of soda (100 pounds per acre) may be advisable to give the onions a start in a cool season, or to stimulate them when growth has been checked by insects, diseases or any other unfavorable conditions.

Propagation. The onion is propagated by seed sown where the crop is to mature; by seed sown in a greenhouse, hotbed, or in an outdoor seed bed; by sets grown from seed sown the year previous; by top sets, which are produced in the flower cluster of the Egyptian or tree onion; and by bottom sets in the multiplier or potato onion. The multiplier seldom

produces flowers and seeds. The small bulb or set grows into a large one which again breaks up into small ones.

A large part of the dry bulb onion crop produced in the United States is grown from seed sown where the crop is to mature. In the South this method is not used because the onions mature before they reach marketable size.

Seedlings are used for the production of early onions to some extent by market gardeners and almost exclusively by growers of Bermuda onions in Texas and of the Valencia or Denia and other large foreign onions in various sections. The use of seedlings is not practicable except in regions where cheap labor can be secured, as in the Bermuda onion regions of Texas where Mexicans are employed.

Sets are used for the production of green bunching onions; for the production of an early crop of dry bulbs for market in the North; to a considerable extent, for bulbs for home use in nearly all sections of the country and in growing common varieties for home use and for market in the South. Onion sets ½ to ¾ inch in diameter are considered the most desirable size. If they are very small they produce weak plants and if above ¾ inch they are likely to send up seed stalks before the onions reach marketable size. Sets usually produce a larger yield than seeds on ordinary upland soil, but on muck soil it is doubtful if this is true. Lloyd (88) has reported results of experiments conducted at the Illinois Experiment Station on a brown silt loam soil. In these experiments yields from seeds and sets were compared for Yellow Globe and Prizetaker varieties covering a period of 6 years. A summary of the results from these experiments is given in Table XXXII.

Table XXXII.—Comparison of Yields, Time Required to Mature and Cost of Growing from Seeds and Sets of Two Varieties of Onions
(Data from Ill. *Bull.* 175)

Variety	Yield per acre, bu.		Number days to mature		Cost of growing per acre	
	Seed	Sets	Seed	Sets	Seeds	Sets
Yellow globe...	345.74	459.02	137	112	101.77	154.69
Prizetaker*.....	373.47	610.99	137	114	$107.17	$126.31

* Prizetaker comparison for 3 years only.

The cost of growing an acre of onions was greater from sets than from seeds, due to the increased cost of the sets themselves. The amount of labor for growing the crop was 328.60 hours for seed and 303.49 hours for sets. The greater amount of labor required from onions grown from seed was largely in the tillage, and in weeding and thinning. The gross returns and profits were greater from the onions grown from sets than those

produced from seed due to the larger yield and higher price received for the former. The higher price was due to earlier maturity and a larger percentage of large onions.

Planting.—The best time for planting depends upon the locality, the type of onions and the method of propagation used. In the North sets for green onions, or for dry bulbs are usually planted as early in the spring as the soil can be prepared, since light freezes do not injure them. When the multiplier onion is used the sets are usually planted in the fall. Seeds of the common onion, when planted where the crop is to mature, are sown as soon as hard frosts are over in the spring in regions where severe freezes occur. In the South the onion is grown as a winter crop and seeds, sets and seedlings are planted in fall or winter depending upon the locality and the type of onion grown. In Texas the Bermuda onion is grown from seedlings produced in an outdoor seed bed, where the seeds are sown in October. The plants are set out usually in December.

Early planting is important in most all regions where spring planting is practiced. Lloyd (88) has shown that at Urbana, Illinois, on a brown silt loam soil, the earlier the crop is planted the higher the yield, other factors being the same. He has also shown that there is not a close correlation between date of planting and time of maturity. Results of 6 years' experiments reported by Lloyd are given in Table XXXIII.

Table XXXIII.—Yields of Onions Planted at Different Dates, Average Number of Days from Planting to Maturity, and Value of Crop per Acre

(Data from Ill. *Bull.* 175)

Average date of planting	Average yield bushels per acre			Average number of days to maturity	Value of crops per acre
	Total	Large bulbs	Small bulbs		
March 27	345.74	323.82	21.92	137	$243.92
April 13	317.75	295.93	21.82	124	219.95
April 28	219.33	198.21	21.12	113	153.41
May 11	218.78	174.29	44.49	110	153.69

Examination of the above table shows that the yields from the first two plantings were much higher than from the last two, also that the percentage of large bulbs was greater from the early plantings. The value of the crop was considerably greater from the first two plantings than from the last two, due to greater yield, higher percentage of large bulbs and to slightly earlier maturity.

Methods of planting are very much the same in the various regions. Seed is sown with a drill when the crop is grown commercially and 4 to 6 pounds are used to the acre if sown where the onions are to mature. Gang planters which sow 4 or more rows at a time are often used where

large acreages are planted. These are drawn by a horse, or a small tractor. Bermuda onion seed is sown in beds and 3½ to 4 pounds of seed are planted for each acre of bulbs to be grown. This allows for discarding the weak plants. Onion sets are commonly planted by hand and a large amount of labor is required. Ten to fifteen bushels of sets are usually planted. For bunching onions the sets are planted an inch or two apart and for bulbs they are set about 3 inches apart. Seedlings are set 3 to 4 inches apart for common onions and for the Bermuda varieties. The plants are usually cut back to reduce the top before setting. Planting is done by hand.

The usual distance between rows is about 14 inches for hand cultivation, the method most commonly used, and 18 to 24 inches for horse cultivation. However, a method of planting in double rows, 6 to 8 inches apart with 16-inch spaces between the sets of rows, is practiced to some extent in Texas. Horse cultivation is given between the sets of double rows.

Thinning.—The practice of sowing onion seed thickly and then thinning the seedlings to the desired distance was practiced quite commonly 15 to 20 years ago. At the present time the tendency is to sow the seed more thinly and dispense with thinning since this is is an expensive operation. Results of experiments on a brown silt loam soil in Illinois (88) show that thinning does not pay under average conditions. Table XXXIV gives the results of these experiments covering 4 years 1908, 1909, 1911 and 1912.

TABLE XXXIV.—COMPARISON OF YIELDS AND COST OF GROWING ONIONS THINNED AND NOT THINNED
(Data from Ill. *Bull.* 175)

	Average yield, bu. per acre			Average cost of growing and harvesting per acre*
	Total	Large	Small	
Thinned	338.34	308.13	30.20	$52.89
Not thinned	396.83	309.89	86.94	45.23

*Figures include cost of weeding, thinning and harvesting only since cost of planting and cultivating were the same.

The figures in the above table show that the total yield of onions was greater in the unthinned plat and while the percentage of large bulbs was greater on the thinned plat the actual yield of these bulbs was nearly the same on the two plats.

On muck soil thinning is of less importance than on mineral soils since muck is very light and there is no danger of producing deformed bulbs even where they are crowded. Large yields are secured where the

onions are grown quite thickly and since large size is of no importance for common onions thinning is seldom justifiable.

Cultivation and Weeding.—To produce a good crop of onions it is essential that the weeds be kept under control and that a surface mulch be maintained to conserve moisture. The onion has a very sparse root system and proper cultivation conserves moisture even when weeds are eliminated. (See Chapter X.)

Cultivation usually begins as soon as the plants appear above the surface of the soil and continues until the tops seriously interfere with the work. Hand cultivation, with shove hoes, wheel hoes and onion weeders, is practiced to a very large extent. Onion weeders are used by some growers to help keep the weeds under control between the plants in the rows. These are quite satisfactory on very light soils when the plants are small but after the tops have straightened up. If they are used before the tops have straightened up many of the plants are pulled out. To do good work, weeders must be used when the weeds are very small and before a hard crust is formed on the soil. Some growers have tried weeders and discarded them on account of apparent injury to the plants and unsatisfactory weed control. In many cases the injury was not as serious as it appeared immediately after the weeder was used. In other instances the weeds were allowed to get too large before the weeder was used. Judicious use of the weeder on a loose soil will reduce the expense of hand weeding. Cultivation between the rows is practiced to keep down weeds and to maintain a surface mulch. For weed destruction shove hoes and the blade attachments of wheel hoes are more satisfactory than the teeth or shovel attachments used on hand cultivators.

Hand weeding is the most laborious and most expensive operation connected with growing the crop. Even where the onion weeder is used hand weeding is necessary. This is often done by women and children who crawl along the rows and remove all the weeds between the plants in the row. In wet weather it is necessary to remove the weeds from the field to prevent them from taking root after being pulled. In a study of onion growing in Massachusetts it was found (Mass. *Bull.* 169) that it required on an average 21 days' labor per acre to weed onions. In addition 5 days were required for cultivating and 4 days for shove hoeing.

Varieties.—There are two general types of onions grown in America for use as dry bulbs. They are usually designated as the "American" and the "foreign" or "European" types. In general the American onions produce bulbs of smaller size, denser texture, stronger flavor and better keeping quality. Three distinct colors of American onions are recognized, red, white and yellow. Probably 75 per cent of the bulb crop consists of yellow varieties. Onions vary in shape from oblate to globular, the latter being preferred on the market. The most important varieties of yellow onions are Yellow Globe, Yellow Globe Danvers,

Danvers, Southport Yellow Globe and Ohio Yellow Globe. Of the red varieties, Southport Red Globe and Red Weathersfield are the best known. Southport White Globe, White Pearl, Silverskin and White Queen are the most popular white varieties.

Of the foreign onions the Bermuda is the most popular, thousands of acres of land being devoted to this crop in Texas. Crystal Wax, White Bermuda (also called Yellow Bermuda) and Red Bermuda are the varieties grown. The White Bermuda which is really yellow in color is the most popular variety and the Red Bermuda the least popular. Denia (also known as Valencia) is grown to some extent in the Southwest and in California, but most of those consumed in this country are imported irom Spain. The Denia is grown by the transplanting method and the bulbs grow to large size, 3 to 4 inches in diameter. The bulb is globular. Prizetaker, another foreign variety, is somewhat similar to the Denia, a little stronger in flavor though milder than any of the American varieties. A type of onion grown in the vicinity of New Orleans known as Creole probably belongs to the "foreign" group.

In addition to the varieties and types mentioned White Multiplier, and Yellow Multiplier (potato onion) and the Egyptian or Perennial Tree onion are grown for early bunching onions. These are very hardy.

Onion Smut.—Onion smut (*Urocystis cepulae*) is probably the most destructive disease of onions. It is of importance in practically all onion-growing regions of the North, but has not appeared in the onion-growing regions of Texas and Louisiana. Walker and Jones (172) explain this on the basis of difference in soil temperature. Results of experiments conducted by them at the University of Wisconsin show clearly the relation between the growth of the organism and soil temperature. They give the following summary of their results:

The relation of soil temperature to the development of the host and the parasite was studied by growing plants in pots held experimentally at a series of constant soil temperatures in the special apparatus known as the Wisconsin soil temperature tank.

Seed germination and growth took place over a range of soil temperature from 10 to 30 degrees C. Most rapid seed germination and development of tops occurred at soil temperatures of 20 to 25 degrees, while as a rule the best development of roots occurred below 20 degrees.

A high percentage of plants grown on smutted soil were infected at soil temperatures ranging from 10 to 25 degrees C. A decided reduction in infection was noted at about 27 degrees, and complete freedom from the disease resulted at 29 degrees. In these experiments all plants were under uniform conditions of air temperture, which ranged from 15 to 20 degrees.

The relation of variations in air temperature to the development of the disease was then studied.

Exposure of plants bearing incipient infections of the fungus in the aerial parts to an air and soil temperature of 30 to 33 degrees C. so disturbed the

relations between parasite and host as to preclude any further development of the disease. This was shown by growing plants at a temperature favorable for infection (15 to 20 degrees). Then, just as the pustules of the disease were beginning to appear (tenth to twelfth day), the plants were removed to a room held at 30 to 33 degrees. This stimulated top growth for a few days, which was followed by a decided checking of the plants and death after three or four weeks. However, if after 12 to 15 days at the high temperature, the plants were returned to the original temperature (15 to 20 degrees), they grew normally, but the fungus in nearly all cases failed to produce spores, and the plants remained free from further invasion.

Experiments were then performed in which seedlings were grown on infested soil held at 20 to 25 degrees, and 30 degrees C. with a uniform air temperature of 30 to 33 degrees. A high percentage of infection resulted at soil temperatures of 20 to 25 degrees, but none at 30 degrees, showing that high air temperature alone is insufficient to check the development of the disease. It appears probable that the failure of the fungus to complete its development in the case described above (where the plants after infection were exposed to an air and soil temperature of 30 to 33 degrees) was brought about at least in part by some marked disturbance of the metabolism of the host and not simply by the direct effect of the high air temperature upon the fungus in the aerial parts of the seedling.

Comparison between the development of the disease in plants grown at 15 to 20 degrees and at 24 to 28 degrees C. (air and soil) was made. A high percentage of cotyledon infection occurred in both cases. At the lower temperature the disease proceeded as usual to the infection of the true leaves. At the higher temperature, however, the plants tended to outgrow the disease, this being associated with a more rapid rate of top development which apparently enabled the plants to slough off the smutted cotyledons before infection of the first true leaf occurred.

The foregoing conclusions as to the dominant influence of soil temperature upon onion smut infection, while primarily based on greenhouse experiments, have been found to accord well with field developments.

Successive out-of-door plantings at Madison, Wis., made in inoculated soil during the growing season, resulted in a gradual reduction of infection as the season advanced and the soil temperature rose. Complete freedom from smut was attained when the daily mean soil temperature at 1 to 2 inches depth remained at or slightly above 29 degrees C. for 2 to 3 weeks. There was also a tendency, as the temperature rose, for the seedlings to outgrow the disease by the sloughing off of the diseased cotyledons before infection of the first leaf occurred.

An examination of records from one of the southern onion sections (Laredo, Tex.) shows that during a good share of the critical period for onion smut infection (August and September) the mean air temperature is above that at which complete inhibition of infection was attained in our experiments (29 degrees C. or about 84 degrees F.). If we assume, as observed in northern sections, that the mean temperature for the upper layer of soil is several degrees higher than that of the air at this time of the year, it is reasonable to conclude that even though the smut organism were introduced into southern onion sections, its development would be prevented or greatly minimized, first, by the prevention of infection due to high temperatures, and, secondly, by the rapidly developing tops out-growing the disease, should occasional infections occur.

In general we believe, therefore, that the regional distribution of onion smut in the United States is conditioned upon the soil temperature during the seedling stage of the plant's growth, the infection and development of smut being favored by the relatively low temperatures and inhibited by the high temperatures, with approximately 29 degrees C. as the critical point.

It is hoped that the evidence here recorded may lead to the accumulation of further field data bearing upon this particular problem by investigators in various places, especially in the southern states. It is also believed that these results illustrate well the importance of more persistent inquiry by the experimental method into the relation of environmental factors to the occurrence of disease of plants in general.

Onion smut can be controlled by applying a solution of formaldehyde (1 pint commercial formaldehyde to 16 gallons of water) in the furrow with the seed. About 200 gallons of the solution to the acre is the usual application and it is applied in a small stream through a tube connected with a tank on the seed drill. The outlet end of the tube is placed just in front of the covering attachments of the drill. The formaldehyde treatment is not expensive and is very effective. Increase in yields of 200 bushels to the acre due to the treatment is not uncommon.

Onion Mildew.—Mildew (*Peronospora schleideniana*) may be recognized by the fungus coating on the outer surface of affected leaves. Affected plants turn yellow and finally die. The disease usually appears at a few points in the field and spreads under favorable conditions of moisture. Spraying with Bordeaux mixture, to which resin fish-oil soap has been added, is sometimes recommended, but it has not been found practicable to apply the material. Burning the dead tops to prevent the fungus from wintering over in them and rotation of crops are recommended.

Onion Thrips.—Onion Thrips (*Thrips tabaci*) are small, black, sucking insects which attack the leaves of onion plants giving them a blanched appearance. The tender, center leaves become curled and deformed and the outer leaves turn brown at the tips. Thrips are most injurious during dry weather and are seldom very destructive during rainy periods, since the rain knocks many of the insects off and kills them. Spraying with tobacco extracts and soap before the leaves turn down will aid in keeping this insect under control. Spraying for thrips has not become a common practice because of the difficulty of applying the material. Many growers, who have tried spraying, have waited until injury was very evident, which, in many cases, was after the tops had begun to fall over. Poor results were secured and spraying was declared to be of no value in thrips control.

Onion Maggot.—The onion maggot (*Phorbia ceparum* and *P. fusciceps*) is the larva of a small fly resembling the common house fly, but smaller. Eggs are laid on the plants near the base or in cracks of the soil. The small maggots, about 1/3 inch long, kill the young plants and later burrow into the bulbs, causing decay. Since the maggots enter the tissues and

eat from the inside poisoning by spraying is impossible. A poisoned bait to attract and kill the flies before the eggs are laid has been recommended. This bait is made as follows:

Sodium arsenite	1/5 ounce
Water	1 gallon
Cheap molasses	1 pint

Dissolve the sodium arsenite in boiling water and add the molasses. This may be sprayed on the plants with a coarse nozzle so that the material will collect in large drops, or it may be distributed in fifteen to twenty small pans for each acre. The liquid needs to be renewed after heavy rains and when dried out.

Yields, Costs and Returns.—The average yield of onions through a period of years for the principal onion-producing states is about 300 bushels per acre, although any good grower expects an average of at least 400 bushels. The average yield on 50 muck farms in Northern Indiana and Southern Michigan (*Farmers Bull.* 761) in 1914 was 421 bushels per acre. In the Connecticut Valley of Massachusetts the average yield in 1913 was 336 bushels and in 1914, 460 bushels (Mass. *Bull.* 169). The average yield on 86 farms, on which studies were made by the Massachusetts Experiment Station, was 527 bushels to the acre in 1914.

The cost of growing onions is so variable that estimates are of little value. However, results of studies made by the Massachusetts Experiment Station (20) are interesting and valuable in showing the distribution of costs on 86 farms. The cost of growing and harvesting averaged 31 cents per bushel where the land owner produced the crop and 35 cents when the crop was grown by a renter. The itemized costs of the land owner were as follows:

Rent (calculated at 5 per cent)	$ 15.00
Interest on value of equipment (calculated per acre)	2.97
Taxes on land valuation $60. Rate $18 per $1,000	1.08
Depreciation of equipment per year	3.40
Fertilizer 3,000 pounds at $34 per ton	51.00
Seed 6 pounds at $1.30 per pound	7.80
Labor for fitting land and sowing fertilizer:	
11 2-horse hours at 50 cts	5.50
4 hours' drilling in seed at $1.75 per day	0.70
Labor for tending crop:	
21 days' weeding; 4 days' shove hoeing; 5 days' cultivating — 30 days at $1.75	52.50
Labor, pulling:	
1½ days at $1.75	2.63
Total cost per acre	$142.58
Total cost per bushel (460 bushel per acre)	0.31

The total cost of preparing a bushel of onions for market and loading into the car, or putting into storage was 6.8 cents, distributed as follows:

Topping	$0.040
Screening	0.017
Hauling	0.011
Total	$0.068

Adding 31 cents, or the cost of growing a bushel of onions, gives a total of 37.8 cents, delivered at storage or depot. These costs do not include shipping containers.

The cost of growing and harvesting is about the same for a small crop as for a large crop. For a yield of 300 bushels per acre the cost of growing and pulling would be 47.5 cents and the handling 6.8 cents, making a total 53.4 cents per bushel for growing and preparing for market. This is slightly more than the average price received by the farmer in Massachusetts in the three-year period 1913–1915 according to Cance, Machmer and Read, who state that the average price received by the farmer during this period was $1.14 per 100 pounds.

Harvesting.—Onions for use in the green stage are harvested as soon as they reach edible size. It is a common practice to make several pullings, removing the largest plants each time and leaving the others to develop. The plants are pulled by hand, the roots trimmed and the outside skin peeled off, leaving the stem clean and white. The onions are then tied in small bunches, the number depending upon the size and the local custom. Green bunching onions are not shipped to any great extent, but the industry is limited to small plantings by market gardeners.

In order to take advantage of the early market, Bermuda onions are harvested as early as possible, generally before the tops have ripened. These onions are not kept for any considerable period, therefore it is not essential that they be ripe when harvested.

Northern-grown bulb onions of the common type are usually allowed to ripen before being harvested. This is especially important if they are to be stored for an immature onion is easily injured and will not keep well. The tops should ripen down and the outer skin of the bulbs should be dry before they are pulled. Most of the bulbs grown commercially are pulled by hand and placed in windrows, consisting of 6 to 8 rows of onions. They are placed in such a way that the tops partially cover the bulbs and protect them from the sun. They are left in the windrows long enough for the tops to wither completely. The length of time required depends upon the weather and may be 3 days or 10 days to 2 weeks. If rain occurs during this curing the onions should be turned with a scoop fork or a wooden rake so that they will dry thoroughly.

After the onions are dry the tops are usually removed and the bulbs placed in crates for further curing. The tops are cut off by hand, using ordinary sheep shears, care being taken not to cut too close. A half-inch to 1 inch of the tops should be left on the bulb. In some sections onion topping machines are used and in this case the onions are put up in crates and hauled to a central location and run through the topper. This machine removes the tops, grades the bulbs into two or more sizes, and delivers them into the crates or bags.

Curing.—Onion bulbs that are to be sold during the winter are usually thoroughly cured before being placed in storage. Where crates are used for the curing, the bulbs are placed in them as soon as the tops are removed. The filled crates are usually stacked in the field, where the stacks are covered with boards, roofing paper or other covering to protect the onions from injury by sun and rain. Sacks are sometimes used instead of crates. They are filled and set upright on poles, or boards to keep them off of the ground. A third method of curing is sometimes practiced, namely, curing in slatted cribs similar to corn cribs. In fact, corn cribs are often used for this purpose. This method has the objection of requiring extra handling which adds to the expense and also injures the bulbs. Sometimes the crates are stacked in open curing sheds instead of being covered in the field.

The length of time required for curing depends largely upon the weather conditions and the type of container used. Thorough curing requires 3 or 4 weeks and even longer in some seasons. Very often they are left in the field, or curing shed until marketed or until freezing weather when they are put into storage houses.

Cleaning and Grading.—After the onions are well cured they are usually run over a sorting rack where the "thicknecks" and injured or decayed bulbs are picked out, while the dirt and small bulbs fall through the slats. At the same time the dry loose outer scales are rubbed off leaving the bulbs bright and clean. The sorting rack is often made so that the bulbs can be graded into two or more grades, based on size, as they pass down over the rack. The very small onions, those below 3/4 inch in diameter, fall through the first section of the rack and those between 3/4 inch and 1 1/4 or 1 3/8 inches fall through the second section and the large bulbs pass on out at the ends. If only one market grade is made the slats or rods of the sorting rack are generally 1 1/4 inches apart, so that all onions above that size pass over and those below fall through and are discarded.

The Bureau of Markets, United States Department of Agriculture, recommends three grades for northern-grown onions (all varieties grown in the United States except Bermudas, Denias and Creoles), U. S. Grade No. 1, U. S. Grade Boilers and U. S. Grade No. 2. The specifications for these grades are as follows:

U. S. Grade No. 1 shall consist of sound onions of similar varietal characteristics which are free from doubles, scullions, and sprouted onions and practically free from dirt, tops, or other foreign matter, and damage caused by disease, insects, or mechanical or other means. The diameter shall not be less than 1¼ inches.

In order to allow for variations incident to commercial grading and handling, 5 per cent by weight of any lot may be under the prescribed size, and in addition, 5 per cent by weight of any such lot may be below the remaining requirements of this grade.

If any lot which meets the requirements of this grade contains more than 25 per cent by weight of onions with diameters from 1¼ to 1¾ inches, inclusive, the grade name shall be "U. S. Grade No. 1, Medium."

If any lot which meets the requirements of this grade contains more than 90 per cent by weight of onions with a diameter greater than 2¼ inches the grade name shall be "U. S. Grade No. 1, Large."

U. S. Grade Boilers shall consist of sound onions of similar varietal characteristics which are free from doubles, scullions, and sprouted onions and practically free from dirt, tops or other foreign matter, and damage caused by disease, insects, or mechanical or other means. The diameter shall not be less than three-quarters of an inch nor more than 1⅝ inches.

In order to allow for variations incident to commercial grading and handling 5 per cent by weight of any lot may vary from the prescribed size, and, in addition 5 per cent by weight of any such lot may be below the remaining requirements of this grade.

U. S. Grade No. 2 shall consist of onions which do not meet the requirements of any of the foregoing grades.

The following definitions are given of the terms used:

"Double" means an onion which, by splitting into two parts has broken the outer skin.

"Scullion" means an onion which has a thick neck and a relatively small and poorly developed bulb.

"Practically free" means that the appearance shall not be injured to an extent readily apparent upon casual examination of the lot.

"Diameter" means the greatest dimension at right angles to a straight line running from the stem to the root.

Packing.—Onion bulbs are placed upon the market in crates, hampers, round-stave baskets, bags, and, to some extent in bulk. The folding crate of the Cummer type is used almost exclusively for Bermuda onions, and to some extent for common onions, especially for the white varieties. In some regions bushel hampers and half-barrel hampers are used for shipping early onions. Coarse-mesh bags, holding 100 pounds or more, are the most common shipping containers for onions as these are cheaper than any other. Only clean bags should be used. The main objection to the use of bags is that they do not protect the onions against injury by bruising, in handling.

No special method of packing is used, but it is important that the containers be well filled to prevent the bulbs from rolling around. If the onions have been in storage for some time they should be regraded before being packed so as to remove any bulbs which have begun to decay or are otherwise injured.

Storage.—Onions to keep well must be well ripened and thoroughly cured before being placed in storage. Immature, soft and thick-necked bulbs should not be placed in storage but sold as soon as harvested.

The essentials for successful storage are thorough ventilation; uniform, comparatively low temperature; dry atmosphere; and protection against actual freezing. Ventilation is provided by openings near the floor and through the roof of the storage house, but to insure circulation of air through the onions it is necessary to provide air spaces between the containers used. Where crates are used the tiers are separated by 1-inch strips and a space of 1 inch or more is left between the rows of crates. Bin storage is used to some extent, especially in Massachusetts. The bins are usually 8 feet wide and 15 feet deep, having portable shelves which slide into position on supports at each side. The onions are placed 6 to 8 inches deep on the shelves allowing a 2-inch space for air circulation above each shelf.

A temperature of 32 degrees F. or slightly below is considered almost ideal. It is impossible to maintain a temperature near the freezing point in common storage houses during periods of warm weather. Effort should be made to keep the temperature as low as possible during such periods by opening the houses during the coolest part of the day.

To maintain a low degree of humidity the house should be built entirely above ground and the ventilators and other openings should be kept closed during cloudy or rainy days. In some instances, a drying agent, usually calcium chloride, is used to absorb the moisture from the atmosphere. This material is very often used in cold-storage houses and is very important when the temperature is allowed to go above the freezing point and cause melting of ice from the refrigerator pipes.

Common storage houses, built especially for storing onions are used for a large part of the stored crop. These houses are constructed of wood, hollow tile, cement blocks, reinforced concrete, or bricks, and are so built as to be nearly air-tight when closed. The walls and ceilings are well insulated by being doubled, trebled or even quadrupled with air spaces, or some insulating material between the layers. The general principles of construction of the common type of onion storage houses are practically the same as given for sweet potato storage houses. (See Chapter XXIII.)

Cold storage is being employed to a considerable extent for onions and is increasing in importance each year. In cold-storage warehouses it is possible to maintain a low temperature throughout the storage

period, thereby keeping the bulbs in a dormant condition. The temperature should be kept at or below the freezing point to prevent drip from the pipes. There is no danger of freezing the onions unless the temperature goes below 28 degrees F. and remains there for a considerable period.

Cost of Storage.—A study of the cost of storage in Massachusetts was made in 1914–1915 (20), covering 22 houses with a capacity of 486,900 bushels of onions. The overhead cost per bushel was 5.3 cents distributed as follows:

Interest on investment including buildings, crates, bins, etc. $211,000 at 5 per cent	$10,550.00
Taxes	2,331.55
Insurance on buildings and equipment	2,500.00
Insurance on onions 486,900 bushel at 30 cts., $6 per $1,000	876.42
Depreciation at 3½ per cent	7,385.00
Repairs 1 per cent	2,110.00
Total overhead charges	$25,752.97
Overhead charges per bushel	$0.053

In addition to the overhead charges other items must be included, such as shrinkage, cost of regrading, hauling, etc. Cance, Machmer and Read have the following to say in regard to shrinkage (20):

The data collected from 22 storages show that the shrinkage for the season of 1914–1915 was about 10 per cent of the quantity stored. It is seldom less than 7 per cent for any one year and hardly ever exceeds 15 per cent, except for onions held until the very last of the season. The crop of 1915 was unusual in this respect. The wet season of 1915 caused the onions to become affected with "slippery skin" and "center rot," so that losses as high as 35 per cent were reported. The average shrinkage, however, probably did not exceed 20 per cent.

Shrinkage losses as well as the cost of extra handling must be considered in computing the total cost of storage. In figuring the shrinkage loss, the value of the onions stored is taken at $1.14 per 100 pounds, which represents the average price paid to the farmers for the three years 1913–1915.

The cost of extra handling from storage and loss by shrinkage on the basis of 250 bags would be as follows:

To regrade and sack, 5 men 1 day at $1.75	$ 8.75
To load and unload 1 man 2 hr. at 17½ cts	0.35
To haul to station, man and team 1 day	5.00
Shrinkage 25 bags at $1.14	28.50
Total cost shrinkage and handling	$42.60
Total cost per bushel (450 bushels)	$ 0.095
Cost per bushel not including shrinkage	0.031

Combining the overhead charges with the charges for removal from storage and shrinkage makes a total cost per bushel of 14.8 cents. The usual charges for storage in commercial houses in Massachusetts

in 1914–1915 was 23 to 25 cents per bag of 2 bushels not including shrinkage. This compares with an actual average cost of 17 cents per bag.

Growing Onion Sets.—Onion sets are small bulbs produced from seed sown very thickly. A large part of the set crop of the United States is produced in the vicinity of Chicago, although a few are grown near Louisville, Kentucky; Chillicothe, Ohio; and at a few other points.

The best soils for onion sets are loose sandy loams, and silt loams. While rich soils are not especially desired, the areas devoted to onion sets contain soils much above the average trucking soil in quality. The size of sets on these soils is controlled largely by very thick seeding. Even with a heavy rate of planting some of the bulbs grown are too large for sets and are usually sold as "picklers." Bulbs over ¾ inch in diameter should not be used as sets.

The amount of seed used for growing sets is determined by the richness of the soil. On poor soils 40 to 60 pounds are used, on medium rich soils 60 to 80 pounds and on rich soils 80 to 100 pounds of seed are planted to the acre.

The seed is sown by hand seed drills or by gang drills of the types used for planting seed for large onions. Some growers use special seeders which distribute the seed in several rows about an inch apart; others place a funnel-shaped spreader on the spout, which distributes the seed over an area 3 or 4 inches in width. The distance between rows is usually 12 to 14 inches although closer planting is sometimes practiced.

The general methods of culture are the same for onion sets as for large bulbs.

In harvesting sets they are first loosened by means of an onion harvester, an attachment for the wheel hoe, which runs under the row. They are gathered in bushel baskets and dumped into shallow, slatted trays to dry. Topping is seldom necessary since the small tops shrivel up. The trays of sets are left spread in the field for a day or two then they are piled one above the other in the field with a space of 3 or 4 inches between. A temporary roof is placed over the pile of trays. The sets are left in the field until they are quite dry, then they are screened and removed to the storage house. The sets are stored under conditions similar to those used for large bulbs.

LEEK

The leek (*Allium porrum* Linn.) is a biennial grown for its blanched stems and leaves. It is believed to be a native of the Mediterranean region, where it has been in cultivation since prehistoric times. It was known by the ancient Greeks and Romans. It is not grown in this country to any great extent, but is produced on a small scale by market

gardeners near large cities, and is consumed largely by the foreign population.

Leeks are propagated entirely from seed, which may be sown in a greenhouse or hotbed, the young plants being transplanted in the garden at the proper time, or they may be sown in rows where the crop is to mature. The method of planting and the distance are about the same as for the onion except that leeks are given a little more space, 4 to 5 inches in the row. In fact the general culture of the crop is very similar to that given the onion, except that leek plants are blanched by banking with soil. The soil is worked up to the plants gradually as they grow, care being taken not to bank up too early as the plants decay easily when young.

The varieties of leeks catalogued by American seedsmen include London Flag, Scotch Flag, Giant Carentan and Large Musselburgh. These varieties are not very distinct and it is probable that the last two are the same.

Leeks are marketed in bunches like green onions. They are eaten raw alone or in mixed salads, and cooked as flavoring in soups and stews.

GARLIC

Garlic (*Allium sativum* Linn.) is a hardy perennial plant native of southern Europe. It was known to the ancients and is said to have been disliked by the Romans on account of the strong odor, but was fed to their laborers and soldiers. It was used in England as early as the first half of the sixteenth century.

Garlic differs from the onion in that, instead of producing one large bulb, it produces a group of small bulbs called cloves. This group is covered with a thin skin. The seed stalk is similar to that of the onion and bears both seeds and bulblets in the same head. The seed, however, is seldom used for propagation as the cloves and bulblets give better satisfaction. Cloves are more commonly used.

A rich sandy loam soil is considered best for garlic although any soil that produces good onions will produce garlic. In Louisiana and Texas where garlic is grown commercially to some extent, plantings are made in the fall, but in northern regions should be made in the spring. The cloves are planted like ordinary onion sets, about 4 inches apart in rows 12 to 18 inches apart. Cultivation, fertilization and general care should be the same as for onions.

As soon as the tops are ripe the bulbs are pulled, and after being left on the ground long enough to dry the tops are woven together in such a way as to hold the bulbs on the outside. The braids, which are usually 4 to 5 feet long, are hung in a dry airy place to cure. After curing several braids are fastened together and sold in this form; or the dry bulbs with the tops removed, may be packed in baskets, bags or other containers. The bulbs are usually sold by the pound.

Garlic is used largely as flavoring in soups, stews and to some extent in pickles. It is not popular with Americans but is grown largely for foreigners, especially those from southern Europe. A considerable quantity is imported since the production in this country does not supply the demand.

SHALLOT

The Shallot (*Allium ascalonicum* Linn.) is believed to have come from western Asia. It is a perennial, seldom produces seeds, but the bulb when planted divides into a number of cloves, which remain attached at the bottom. It has been in cultivation from a remote period. It is mentioned and figured in nearly all old works on botany.

The cloves are planted in spring in about the same manner as described for garlic and the cultivation and care given onions are satisfactory for shallots. The bulbs are harvested when the leaves begin to wither and after being left exposed long enough to dry they are divided and stored in a cool dry place.

Shallots are used mainly for seasoning and give a more delicate flavor than onions. The leaves are also eaten when green.

CIBOUL (CIBOULE) OR WELCH ONION

Ciboul (*Allium fistulosum* Linn.) is a perennial but is grown as an annual or biennial. It is a native of Siberia or the East and was introduced into England about 1629. It does not form a real bulb but only a small enlargement at the base. It is grown for its leaves which are used in salads.

This plant may be propagated by division, or by seeds, the latter being preferred. The seeds are sown where the plants are to grow, giving about the same space as for green bunching onions. The culture given green onions is satisfactory for this crop.

CHIVE

Chive or cive (*Allium schoenoprasum* Linn.) is a perennial, probably a native of Europe. It is not grown to any great extent in America, although it is listed in seed catalogues. The plant grows in thick tufts and produces very small, oval bulbs forming a compact mass. It is always propagated by division of the tufts, since seed is rarely produced. While the plant is perennial it is a good plan to take up the clumps and replant them every two or three years.

Chives are used as seasoning and are much grown in European gardens. They are very popular with the Scotch and are considered almost indispensable in omelettes. The plant is grown for its leaves which are cut off with a knife. The cutting seems to stimulate fresh growth.

CHAPTER XXIII

THE POTATO CROPS

POTATO . SWEET POTATO

The potato or Irish potato and the sweet potato are the most important vegetable crops. While they are not related botanically and their cultural requirements are unlike they are associated in the public mind. They are both starchy foods and in general, their uses in the diet are similar. The word "potato" as used in the North refers to the Irish potato, while in the South it usually refers to the sweet potato.

POTATOES*

The average annual world production of the potato is now between five and five and a half billion bushels having a value nearly, if not quite equal to that of wheat which has for years been recognized as the world's leading food crop. The 4 principal world food crops are corn, wheat, oats and potatoes. Potatoes rank first in total bushels produced and rival wheat in total value. There is probably no food article in the daily diet of the white race more common than the potato. It contains nearly 80 per cent water in its uncooked state. The remainder consists of about 2 per cent protein and 18 per cent starch. The potato is one of the cheapest and most common sources of carbohydrate food.

Statistics of Production.—The average annual world production of potatoes is approximately five billion bushels. Germany produces about one billion, Russia about eight hundred million, France four hundred million, the United States four hundred million, and Austria between two hundred million and three hundred million bushels. More than one-half of the world's crop, therefore, is produced in the 5 countries mentioned.

According to the census for 1919 the rank in value of the principal groups of crops grown in the United States are cereals, hay and forage, cotton, vegetables, and tobacco in the order named. The total value of all vegetables was approximately one and one-third billion dollars and the potato crop had a value nearly equal to all other vegetables combined. Nearly 45 per cent of all farms grew potatoes. These farms reported an average of 1.1 acre per farm, yield of 89.3 bushels per acre

* The material on potatoes was prepared by E. V. Hardenburg, Assistant Professor of Vegetable Gardening, Cornell University.

and an average value of $197 per acre in 1919. The acreage, production, value, yield per acre and percentage of total acreage in potatoes for the leading potato states and for the United States as reported by the last census is shown in Table XXXV.

Table XXXV.—Acreage, Production, Value, Yield per Acre, Percentage of Total Acreage in Potatoes for Principal Potato States According to Census of 1920

State	Acreage in thousands	Production in thousands of bushels	Value in thousands of dollars	Yield per acre in bushels	Per cent of total acreage in potatoes
New York	310	32,471	69,812	104.6	9.5
Minnesota	332	26,690	57,384	80.4	10.2
Wisconsin	294	26,376	60,665	89.6	9.1
Maine	111	25,531	52,340	229.2	3.4
Michigan	281	23,930	49,056	85.3	8.6
Pennsylvania	234	22,052	47,411	94.2	7.2
United States	3,252	290,428	639,441	89.3	100.0

These figures, indicate that over 48 per cent of the total acreage and over 52 per cent of the total crop was produced in 6 states. The fact that these states, with the exception of Pennsylvania, border on Canada or the Great Lakes indicates the importance of cool climate to the potato crop.

The per capita annual consumption of potatoes in the United States varies between 3 and 4 bushels while in western European countries, where production is more intensive, consumption is considerably greater.

Our foreign trade in potatoes is relatively small. Whereas our average annual exportation for 1911 to 1919 inclusive was 3,082,000 bushels, our average annual importation for the same period was 2,508,000 bushels. This leaves an average annual net exportation of only 574,000 bushels.

History and Taxonomy.—The potato is undoubtedly a native of South America where it was in cultivation by the natives long before the discovery of America. In fact it is believed by some authorities that it was cultivated at the time of the Incas (Sturtevant). It probably was carried to Spain from Peru early in the sixteenth century. There is some controversy as to whether the potato was introduced into this country from Europe, or brought direct from South America by Spanish explorers. At any rate, it was known in continental Europe and to the colonists of Virginia almost simultaneously and as early as the latter part of the sixteenth century. It remained for the early English colonists of

Virginia to introduce the potato as a food plant into England about 1586. As a food it did not become generally popular in Europe until the middle of the eighteenth century, some time after being freely eaten by the whites and Indians in the North American colonies. During the next hundred years, however, production developed rapidly throughout temperate Europe and America. The seriousness of the famous Irish famine of 1846, due to loss by blight rot of the potato crop of Ireland in that year, is evidence of the extreme dependence of the masses of western Europe upon this food.

The members of the family Solanaceae, of which the potato is the most important, all contain the chemical solanin. Some of the better known relatives of the potato are tomato, tobacco, pepper, eggplant, henbane, belladonna, petunia, Jimson weed, black nightshade and bittersweet. Of the several hundred species of Solanum, very few have the habit of forming tubers on their underground stems. Of these few tuber-bearing species, only four produce tubers of sufficient size to command commercial attention. These in the order of their importance are *S. tuberosum*, the common white cultivated potato of commerce; *S. commersonii*, a colored form used to a limited extent by the peasantry of western Europe; *S. jamesii*, the wild potato of Arizona used by the Indians of that region; and *S. maglia* the wild potato common to the Rocky Mountains.

The plant attains an average height of two to three feet depending upon variety and environment. The stems are angular, solid and often winged in cross-section and bear compound leaves with leaflets opposite and decreasing in size from apex to base of the leaf. The blossoms are borne in clusters, each consisting of a rotate five-pointed corolla subtended by a similar shaped calyx. The corolla color varies with the variety from pure white to deep purple or violet. The true fruit or seed-ball of the potato is nearly spherical ½ to 1 inch in diameter and in its pulp are from 100 to 300 pear-shaped seeds. Few seed-balls are developed on our present standard varieties, due apparently to such causes as paucity of viable pollen, premature dehiscence of flower buds and degeneration of flower parts. Apparently neither flowering habit nor seedball formation are, however, correlated with tuber yield. The potato tuber represents an enlarged, fore-shortened portion of the underground stem. The tuber is usually borne at the terminus of the stolon although occasionally lateral sessile tubers occur. According to the investigations of Clark (26), tuber formation begins at about the end of the period of flower-bud development and practically the entire crop of tubers is set at this time. Obviously, therefore, the favorableness of soil conditions and of climate during this period in the life of the plant is of immense importance. Clark, from a single years' test of the influence of soil type on the number and yield of tubers per hill in two varieties, found that as the soil type became lighter the number and yield of tubers per hill increased.

Climatic Requirements.—Climate is decidedly a limiting factor in potato production. In its response to seasonal temperature and rainfall, the potato ranks with corn and cotton. The high average annual yields obtained in Maine, in Scotland, Ireland, England and northern Germany are due in large part to the cool growing season of these regions. According to the United States Department of Agriculture (169) of a total average annual loss from 1909 to 1919 of 30 per cent in the potato crop of this country, over 20 per cent was due to adverse weather. Growing season temperatures ranging from 60 to 75 degrees F. are most favorable. Maine is the only state in this country situated north of the 65 degrees isotherm. J. Warren Smith (139) correlated monthly and total growing season temperature and rainfall with the average annual yields of potatoes in Ohio over a period of 55 years. He found a very significant negative relationship between temperature and yield and an almost equally significant positive relationship between rainfall and yield in that state. He also found by the correlation method that July weather is more influential on potatoes than the weather of any other month, doubtless due to the fact that this being the time when the plant is blossoming and setting tubers, is a critical period in the life of the plant. Fox (46) similarly correlated these climatic factors with yield in New York for a period of 26 years and obtained results agreeing with those of Smith except that the rainfall and yield correlation was negative instead of positive. This indicates that whereas rainfall is usually a limiting factor in Ohio, the years of highest rainfall in New York have been years of severe loss in the potato crop from rot due to the late blight fungus, *Phytophthora infestans*. The states having highest average yields in this country are not those leading in total production but rather those intermountain states of the West where the crop is grown on the higher plateaus under irrigation. These limited areas are provided with ideal temperature and moisture conditions through elevation and a controlled water supply. Some of the southern states (180) produce a part of their own seed stock by growing it at the higher mountain elevations in order to take advantage of cool growing season temperatures. Mulching (43) of seed plats is also sometimes practiced, the influence of the straw or other mulch material being to maintain a lower average soil temperature than would otherwise be available. One reason why early or short-season varieties predominate in the southern states is the necessity of growing and maturing the crop early enough to avoid the high temperatures of mid-summer.

Soil Preferences.—Of the two factors, climate and soil, the latter is undoubtedly much less important as a factor limiting yield, than the former. The influence of soil on potatoes is measured in yield, earliness of maturity, eating quality, keeping quality and the loss from disease. The ideal soil for potatoes is one which is naturally rich, of medium tex-

ture, friable, deep and not highly alkaline. Extra light soils are not sufficiently retentive of moisture to supply the normal water requirements of the plant and are usually relatively poor, especially in humus. Extra heavy soils when wet are more conducive to blight rot development in the tubers, and when dry are subject to baking and generally result in greater difficulty in digging the crop. The Wooster series and the Washburn series of loam soils on which the famous yields are produced in Aroostook County, Maine, being of medium to light texture, of glacial drift origin and naturally well supplied with humus, are ideal for this crop. The fairly light soils of northern New York, Long Island, New Jersey and Virginia all produce bright skinned potatoes of excellent eating quality. These sandier soils are inherently lower in potash than the heavier soils farther inland. In many of the older potato-growing regions along the Atlantic seaboard, evidence of so-called potash-hunger has been shown where little potash has been applied in recent years.

Rotations.—Except in a few important potato-producing regions such as Long Island, New York, the eastern shore of Virginia and in the trucking regions of the South, the crop is rotated in cropping systems varying in length from three to five or more years. Ideal soil and market conditions and the relatively high land values on Long Island make the continuous production of potatoes desirable in this region. In recent years, growers have depended upon winter-grown green-manure cover crops of rye to maintain the soil humus supply necessary for the crop under these conditions. Generally, however, potatoes follow a sod crop in the rotation. The most common rotation in Maine is potatoes, oats, clover, while in New York it is potatoes, oats, hay two or three years. The relatively high feeding requirements of the potato makes rotation desirable. This tends to prevent soil depletion and the accumulation of potato disease organisms which live in the soil. Macoun (90) has shown that clover is a very desirable legume crop to precede potatoes. This crop adds humus in a desirable form and has a beneficial influence on soil texture. In the more common 4 to 6-year rotations of potatoes, grain, and hay 2 to 4 years, the sod residue from the older seedings preceding potatoes is often so light as to be of small benefit. In New York (59) the yields were found to decrease with the increase in length of rotation. These low yields were attributed to the poor quality and low yield of humus in the older seedings. Such soil-infesting potato insects as wire worms and grubs are also more numerous and serious when potatoes follow such old seedings. In regions farther west, where potatoes are rotated with such crops as corn, beets, oats and alfalfa the longer rotations have given the highest yields (Holden (73) 1920).

Soil Preparation.—Thoroughness in seed-bed preparation is obviously important from the fact that soil structure, moisture, temperature, aeration and available mineral nutrients are all more or less dependent upon

it and the shape, quality and yield of the tubers in turn dependent on these factors. Heavy soils are often improved in structure and texture for potatoes by growing such crops as rye and buckwheat. The tap-root of the latter tends to loosen the lower, less pervious strata and leaves the entire soil surface in a more friable condition. Rye produces a large amount of organic material in a relatively short time and has the advantage of being hardy and well adapted to acid and poor soils. In its decomposition to form humus, the humic acid formed tends to reduce the alkalinity in soils containing the potato scab organism and thus reduces the loss from this disease. When the crop is to be grown in long rotation with old seedings in which potato insects are often more numerous, corn may profitably precede potatoes, the former instead of the latter following sod. In plowing under coarse corn stubble just before planting potatoes, there is often danger that the undecomposed layer will interfere with the upward movement of water and thus limit the crop. Fall plowing of the heavier soils and of soils carrying coarse organic material is recommended. Very little fall plowing is commonly done, however, because of unfavorable fall weather and competition with other farm work. Shallow soils with hardpan layers close to the surface can be improved for potatoes by a gradual increase in depth of plowing each year to enlarge the soil area suitable for tuber development. Fitting of plowed land for a tilled crop of this kind can scarcely be overdone. Weeds are more efficiently controlled by thorough harrowing prior to planting than by the much more costly and less efficient inter-row tillage during the growing season. Thus it often happens that better final results are obtained by delaying planting until such time as the seed bed is in optimum condition than by early planting and its subsequent difficulties in weed control because of a poor seed bed.

Manures and Fertilizers.—The heavy feeding requirements of the crop and the relatively large gross income per acre from it are factors which make the use of large applications of manure and fertilizer usually not only necessary but profitable. On the sandier soils in the older potato regions of the eastern states, amounts of fertilizer ranging from 500 to 2,000 pounds per acre are commonly applied. On the heavier soils farther inland and particularly in such important potato states as Michigan, Wisconsin and Minnesota lighter applications, 500 pounds or less, are used.

A relatively higher grade of commercial fertilizer is used on potatoes than on other field crops. Judging by analyses of comparative yields of potatoes and corn the potato requires about one-half as much nitrogen and twice as much phosphorus and potassium as the latter. Nearly all complete potato fertilizers analyze high in the last two elements. Before the World War, 2–8–10 was the analysis commonly used. When the war prevented the use of so much potash, growers learned that equally good

yields could be obtained with less. Potato soils had apparently become temporarily stocked with a surplus. Recently, such analyses as 3–8–6, 4–8–4 and 2–8–6 have become common. There are very few soils naturally stocked with sufficiently readily available potash to give good yields. Both sulfate and chloride or muriate forms of potash are used and experiments indicate no appreciable difference between them in their influence on yields. Muriate of potash is more commonly used because it is cheaper and more plentiful in the market. Comparative tests of influence on quality have in a few cases shown that the chlorine in muriate of potash has reduced the quality of potatoes. There is, however, insufficient evidence on this point. Woods (184) reported the results of a 4-year test in Maine to determine the effect of varying amounts of potash on yield. Fifteen hundred pounds per acre of a complete fertilizer containing the same amounts of ammonia and phosphoric acid and mixed with no potash, with 300 pounds of salt and with 3, 5 and 7 per cent of potash respectively were used. Part of the results are given in Table XXXVI.

Table XXXVI.—No Potash Experiment with Potatoes, 1915–1918
(Yield in hundredweight per acre)

Amount of potash	1915	1916	1917		1918	
		Series 1	Series 1	Series 2	Series 2	Average
None	182	172	131	140	123	150
None + salt	...	193	136	144	130	151
3 per cent K_2O	191	254	135	150	128	172
5 per cent K_2O	191	254	131	157	137	174
7 per cent K_2O	198	244	139	160	134	175

Under these conditions, salt did not appear to liberate potash already in the soil nor did it pay to use over 3 per cent of potash. Phosphatic fertilizers used alone quite generally give more profitable results than any other single kind of fertilizer.

Time and method of applying fertilizers are of considerable importance. When planters are used, the fertilizer is commonly applied through a fertilizer attachment just ahead of the seed hopper on the machine. This leaves the fertilizer just beneath the seed piece with a slight covering of moist earth between to prevent contact and burning of the latter. When planters are not used, grain drills, or fertilizer distributers are common. Sometimes the application is made by broadcasting in the open furrow just prior to dropping the seed by hand. This may give

good results but may cause burning of the new sprouts as they develop. For this reason it is seldom advisable to drop fertilizer in the hill with the seed piece. Growers in Maine commonly apply a part of the fertilizer through the planter at planting time, a second application being distributed as a side dressing soon after the plants are established. Nitrate of soda is usually used in the late application in order to hasten top growth. Results of 3 years' experiment at the Maine Station (185), indicate that when as much as 1,500 pounds of fertilizer are used, it is fully as efficient to apply it all at one application and through the planter as to apply it in two applications, or broadcast. Similar results were obtained at the Storrs (137), Connecticut Station in a 4-year test. The New York Station (81) comparing drilling with broadcasting in a 4 years' test on Long Island obtained a difference of 7.3 bushels per acre in favor of drilling. Apparently the drill method is to be recommended when the additional factor of cheaper cost of application with the planter is considered.

Stable manure, well decomposed, has long been recognized as a very desirable form of organic fertilizer for potatoes. When the crop is grown on a small scale, it is still commonly used as a top dressing to the sod just prior to plowing. In regions of more extensive production, however, the supply is no longer adequate for the entire acreage. The most efficient place for stable manure in the average rotation is probably as a top dressing to the hay crop the year previous to breaking up sod for potatoes. Thus applied, it increases the quality and yield of hay, becomes well incorporated with the soil and of a more available form for potatoes and is less likely to increase scab on the tubers. Farm manures, high in ammonia, because of their tendency to promote activity of the scab organism, should not be applied directly to the potato crop.

Seed.—The majority of growers in the leading potato-growing states produce their own seed potatoes, only renewing from outside sources in occasional years. In contrast, growers on Long Island, in New Jersey, Virginia and the southern and middle western states quite universally procure seed annually from sources farther north. Middle western and Gulf coast states secure seed potatoes mainly from Minnesota, Wisconsin, Montana, the Dakotas and the Red River Valley region of Canada, while the seed used on Long Island, in New Jersey, Virginia and the South Atlantic states is grown mostly in the Maritime provinces of Canada, and in Maine, Vermont and New York. This practice of using northern-grown seed is necessary because the crop as grown under the hot, growing-season temperatures of the South is so devitalized as to render it unfit for seed. What is known as second crop seed is grown to some extent in southern states by planting, late in the summer, northern-grown stock which has been held in cool or cold storage. Planted in late summer, such a crop develops under cooler temperatures and thus

retains sufficient vitality to make it of value for seed the next year. Second crop seed is usually immature when dug and is therefore low in yield and relatively expensive.

The quality of seed potatoes depends upon such factors as disease, storage conditions, and soil and climatic conditions prevailing during growth. Strains of seed do degenerate or "run-out" from such causes as the incursion of non-parasitic diseases and growth and storage under unfavorable temperatures. Immaturity in seed is desirable in so far as it results in less sprout development during storage and a consequent greater vigor and less shrinkage in the seed at planting time. Planting seed stock so late as to prevent its maturity before killing frosts in the fall results in a more desirable type of immature seed than would result by harvesting seed stock planted at the usual time, in an immature condition during mid-summer.

The influence of immaturity of seed on the resulting crop is shown in the results of 4 years' work by Zavitz (188) at the Ontario Station as given in Table XXXVII.

Table XXXVII.—Results from Planting Mature and Immature Seed Potatoes at the Ontario Station (Average of 4 Years)

Seed potatoes obtained from the crops produced from the plantings of the following dates of the previous year	Average percentage maturity in resulting crop on September 11th	Average yield of 6 varieties (24 tests) in bu. per acre
May 31	57	192.37
June 14	56	194.80
June 28	55	201.84
July 12	53	219.46

Although the increased yield due to immaturity is relatively small, the increase is consistent. It is interesting to note that the crop from immature seed was somewhat later in maturing than that from seed which was mature.

Storage of seed potatoes is an important factor too often neglected in common practice. Most seed potatoes are stored in house cellars of dirt floor and stone-wall construction. The average temperature is often high enough to promote early development of sprouts and as a result the seed is badly shrunken and low in vitality by planting time. Seed should be stored, if possible, at uniform temperatures ranging from 34 to 42 degrees F. Although tubers will not usually suffer damage from freezing at temperatures down to 28 degrees F. (4) without refrigeration it is quite impossible to maintain this low range. Low temperature tends to reduce respiration and thereby reduces the rate of loss of soluble carbohydrates and also checks the spread of tuber diseases in storage.

Normal humidity is also important as dry air increases the evaporation rate while excessive humidity promotes the development of storage diseases. Uniformity of both temperature and humidity are best controlled by proper ventilation.

Sun-sprouting or "greening" of seed potatoes, a practice more common in Europe than in America, is annually becoming more common as its benefits are better appreciated. It involves exposure of the seed tubers on the ground or floor to moderate or subdued light for a period of about two weeks prior to planting time. During this time, short, green, vigorous, disease-resistant sprouts are developed and it becomes possible to discard those tubers which develop weak sprouts or no sprouts at all. Sprouts over ½ inch long should not be allowed to develop because of the likelihood of their being broken off in going through the planter. Among the several advantages resulting from the practice of greening are increased earliness, increased yield, a better stand of plants and less disease. Yield, wholly aside from its increase due to greater vigor of the sprouts, is potentially higher because of the greater number of nodes and stolons which develop on the sprout of greened seed between the seed piece and the soil surface.

Three factors determine whether seed tubers should be cut or planted whole, namely: (1) Cost of labor for cutting, (2) cost of seed, and (3) relative efficiency of cut and whole seed. Generally, the comparative costs of seed and labor are such that it is more profitable to cut seed than to plant it whole. Relatively little seed weighing more than 2 ounces, or of hen's-egg size, is ever planted. Most of this is cut. All other factors being equal, whole is better than cut seed because it is less likely to rot or become diseased after planting and because it will not lose vitality through bleeding and drying. Whether small or large tubers are the better for seed depends principally on whether the small tubers are from high-yielding healthy stock or only representative of the culls and small tubers from diseased and low-yielding hills. Stewart (144) has recently reported that uncut tubers between one and two ounces in weight are at least as good as, and, probably better than, pieces of equal weight cut from large tubers of the same plant. In his tests, however, a high-yielding, healthy strain of seed was used. Most experiments comparing yields from large and small tubers have resulted in both total and marketable yield in favor of large tubers. Much more seed per acre was planted, however, when the large seed was used.

Size of seed piece has been shown by numerous experiments to have a very pronounced influence on yield. Nearly all tests which compared one-eighth, one-quarter, one-half and whole tuber seed pieces have resulted in increased total yields for each increase in size of seed used. Most of these tests have shown that as the size of the piece increases, the number of stalks per hill increases, the percentage of marketable yield

decreases, and the total marketable yield increases up to the one-half tuber size. The planting of large whole tubers has therefore, not been generally profitable. With plants spaced equidistant in nearly all of these experiments, the number of bushels planted on an acre was increased as the size of seed piece was increased. Therefore the increase in yield from large pieces is really a measure of the influence of rate of planting. Among the recent experiments, the results obtained by Zavitz (188) in a 5-year test at the Ontario Station as shown in Table XXXVIII are typical:

Table XXXVIII.—Size of Seed Piece Related to Yield at the Ontario Agricultural Experiment Station

Size of seed piece planted, oz.	Eyes per seed piece	Amount of seed used per acre, bu.	Average results for 5 years (10 tests)			
			Percentage of crop marketable	Yield per acre, bu.		
				Marketable	Total	Total less seed used
1/16	1	1.3	61.0	36.8	47.5	46.2
1/8	1	2.6	88.6	78.8	89.7	87.1
1/4	1	5.2	89.7	98.4	111.1	105.9
1/2	1	10.3	88.7	109.4	129.0	118.7
1	1	20.6	89.5	129.9	148.4	127.8
2	1	41.2	87.6	149.7	173.9	132.7

Emerson (44) in Nebraska, made a test of this factor in which the amount of seed per acre was the same for all sizes of seed piece. Planting eighth, quarter and half-tuber seed pieces, 6, 12 and 24 inches apart, respectively, he used 18 bushels of seed per acre in each plat. This gave the highest total yield per acre from the quarter-tuber pieces and the lowest total yield from the half tubers. Apparently the most efficient way to use a given amount of seed is to cut it into pieces about one ounce in size and plant it relatively close rather than to use larger pieces and plant them farther apart.

Many of the older growers pay special attention to number of eyes on the seed piece when cutting seed. This would be important if pieces as small as, or smaller than, one ounce were to be used in order to insure at least one good eye to the piece. But since yield is influenced mainly by size of seed piece irrespective of number of eyes as shown in Table XXXVIII, the question of number of eyes becomes of only minor importance. Ballou (9) in Ohio found that as the number of eyes on the seed increased, the number of stalks per hill increased and the yield of unmarketable tubers also increased. However, he also obtained an increase in marketable yield with each increase in number of eyes. Whipple (178) thinned plats of several varieties in Montana to one stalk per hill and reported a very small increase in marketable yield with

practically no difference in total yield. The most important factor in cutting seed appears therefore to be that of obtaining a sufficiently large piece to insure at least one vigorous stalk and that the piece may not dry out or weaken even under adverse soil conditions between planting time and the complete establishment of the plant. Chunky pieces are most satisfactory as they are less likely to break or dry out, and they feed through the machine planters better than slender pieces.

When seed must be stored for a week or more after cutting, it is a desirable practice to dust the cut seed to prevent loss of moisture from the cut surfaces and to prevent heating of such seed. When seed can be planted at once after cutting, as is generally true, dusting is probably not justified. Such materials as land plaster or gypsum, hydrated lime, sifted wood ashes, road dust and sulfur flour are used. Of these, land plaster which is cheap and probably the most adhesive is used most commonly. Holding cut seed in order to thoroughly dry the cut surfaces before planting is not recommended.

Planting.—Average date of the last killing frost in spring, soil type, and type or variety to be grown are the factors which really determine the best time to plant potatoes. Planting is usually earlier on light soils at low elevations than on heavy soils at high elevations. Since prices are usually higher on the early market than on the late, early planting is more important with early varieties than with late varieties. If possible, potatoes should be so planted as to bring the period of blossoming and tuber-setting during a time when weather conditions are optimum. Hot, dry weather at this critical period in the life of the plant, seriously interferes with the setting of tubers and consequently with the ultimate crop. Under average conditions and with most main-crop varieties, tubers are formed about 6 weeks after the planting date. In the leading potato-producing states, the average date of planting varies from May 15 to June 15. Thus July weather is usually very influential on potato yields.

Although probably more than half the entire potato acreage of this country is still planted by hand, machine planters which drop seed pieces automatically are annually becoming more common. The larger acreages in regions of fairly level topography and few stones are now quite generally machine planted. Of the two distinct types of planters now used, one requires two men, the other one, for its operation. The two-man or platform type which usually costs a little more than the picker type and is more expensive to operate because of the extra man required, is expected to produce a more nearly perfect stand of plants than the latter. Neither type, however, can be used to plant in checkrows. The relative merits of the checkrow and the drill systems of planting are determined by such factors as cost of labor, available mineral nutrients and moisture, value of land, and weed control. The last of these is most important.

Under conditions of hilly topography and heavy soil, weed control is often facilitated by planting in checks to allow cross cultivation. Under more favorable conditions, weeds can be as efficiently controlled and yields increased by planting in drills. There are more plants and usually more seed used on an acre under drill than under checkrow planting. Because of this increased stand of plants and amount of seed, yields are commonly higher on fields planted in drills. The results of a study made by the Cornell (59) Station on 947 farms in New York are reported in Table XXXIX.

TABLE XXXIX.—RELATION OF PLANTING SYSTEM TO YIELD ON 947 FARMS IN NEW YORK

Region	Planted in drills			Planted in checkrows		
	Number of farms	Average yield per acre, bu.	Average amount of seed used per acre, bu.	Number of farms	Average yield per acre, bu.	Average amount of seed used per acre, bu.
Steuben County 1912	101	153.0	12.2	251	129.2	9.2
Monroe County 1913	221	128.5	13.2	77	120.6	10.2
Franklin and Clinton counties 1913	54	188.4	14.5	243	177.2	11.4
Total	376	.....	....	571		
Average	...	156.6	13.3	...	142.3	10.3

The above data indicate that an average of 3 bushels more seed per acre are used under the drill method in New York. The average number of bushels of seed used in most of the leading potato states varies between 10 bushels and 15 bushels per acre. The majority of station experiments indicate that as many as 18 bushels of seed could more profitably be used. In Great Britain and the countries of western Europe as much as 25 to 35 bushels of seed per acre is common. In those countries, potato land is relatively expensive and labor relatively cheap. Under such conditions, hand tillage can be economically used. In regions where mineral nutrients and moisture are likely to be limited, wider spacing of plants and less seed per acre are recommended than in regions where growing conditions are more favorable. Stuart (150) has figures showing the relation of size of seed piece and spacing of plants on the amount of seed required to plant an acre. His tabulation shows that more than 54 bushels of seed would be required to plant an acre if 2-ounce seed pieces were planted as close as 8 inches apart in rows 30 inches apart. But if one-half-ounce seed pieces were planted 36 inches apart in rows 48 inches apart, only 1.9 bushels of seed would be required. The common distance between rows is 3 feet. In checkrow planting 3 feet is the usual distance between plants, while in

drills the average spacing is between 12 and 18 inches. Early varieties which produce smaller foliage growth may be planted much closer than late varieties. The decrease in yield due to missing hills is not in absolute proportion to the number of such missing hills. Stewart (145) in New York found that about one-half of the loss in yield due to a misisng hill is made up by the two hills adjacent to the vacant space.

Depth of planting varies mainly with soil type and with the system of culture. Although 4 inches is about average, the depth is commonly more shallow on heavy soils and deeper on light soils. Irrespective of depth planted, tubers tend to develop at the 4-inch depth. This is due to the fact that conditions of soil moisture and temperature are optimum for growth at this depth. On the heavier soils, the seed is commonly planted quite shallow and a system of gradual to steep ridging is practiced during the growing season. This provides against injury to the crop from excessive rainfall and makes digging easier. Extreme ridging is practiced mainly in Maine, western New York, in the South and in the irrigated sections of the West. Elsewhere more nearly level culture is practiced. In regions where the soil is light and rainfall is likely to be insufficient, ridging is sometimes overdone with the result that the plants dry out and growth is retarded at mid-season.

Cultivation.—The potato, like all other intertilled crops, responds to good cultivation. But tillage may be, and frequently is, overdone. Probably more frequently, however, it is either insufficient or at least inefficient. Of the two primary objects of cultivation, moisture conservation by a soil mulch and weed control, the latter is much the more important. Early season cultivation is of benefit not only in weed control and improved tilth but also in conserving moisture necessary to the young plant. Later, however, when the surface roots, and the shade furnished by the foliage are sufficient to reduce the evaporation from the soil surface, the principal benefit comes from weed control. Therefore, deep and frequent tillage early in the season and shallow infrequent tillage late in the season are recommended. The experiments of both Stone (146) and Emerson (44) indicated that from 6 to 9 cultivations a season were more effective than either a greater or less number. Fewer cultivations would not control weeds while a greater frequency usually resulted in injury to the plant late in the season. Time of cultivation is, after all, more important than frequency. Tillage is of little or no benefit and may be injurious after the tubers have set and the foliage covers the soil surface.

Varieties.—The various and promiscuous methods by which potato varieties have come into existence have resulted in the production of far too many varieties of uncertain origin and commercial value, and in much confusion in nomenclature. Many of our present so-called varieties are the results of selection for change or improvement in type of tuber,

or yield. Many are the results of simply renaming old varieties. There are three methods by which varieties have distinct origin, namely, crossing, mutation, and production of seedlings from spontaneous seed balls. Of these three, varieties from seed balls are most common. Such standard varieties as Sir Walter Raleigh, Norcross, Burbank, Rural New Yorker No. 2, Carman No. 3, Early Rose and Early Ohio originated directly from seedlings. Green Mountain and Delaware are examples of origin by crossing while Pearl, White Ohio and White Triumph are notable examples of the results of mutation. Varieties Number 9 and Heavyweight are the products of selection for increased yield from older varieties of the Rural type. The fact that most of the varieties which were popular sixty years ago are no longer grown extensively has led to a popular impression that varieties "run out" because of senility. Such varieties as Garnet Chili, Black Chenango, Cowhorn, Blue Mercer, Meshannock and Early Peachblow are scarcely found today. There seems to be no valid evidence, however, that they have disappeared because of old age. High-yielding strains of each may still be found in cultivation, but the present potato market is against such colored-skinned, ill-shaped, deep-eyed and poor-quality varieties. The majority of evidence indicates that neither varieties nor strains degenerate with senility alone, but rather that seed stocks do become more or less worthless as they become badly affected with such non-parasitic or virus diseases as leaf roll and mosaic (128). Unfavorable growing season and storage environment are also considered to be contributing factors.

Although hundreds of varieties are being grown throughout the United States, the commercially important ones can be associated into groups on the basis of similarity of foliage and tuber characters and season of maturity of the varieties within each group. Such a group classification and description has been made by Stuart (151). His classification key follows:

Group 1—Cobbler.

Tubers: Roundish; skin creamy white.

Sprouts: Base, leaf scales, and tips slightly or distinctly tinged with reddish-violet or magenta. In many cases the color is absent.

Flowers: Light rose-purple; under intense heat may be almost white.

Group 2—Triumph.

Tubers: Roundish; skin creamy white with more or less numerous splashes of red, or carmine, or solid red; maturing very early.

Sprouts: Base, leaf scales, and tips more or less deeply suffused with reddish-violet.

Flowers: Very light rose-purple.

Group 3—Early Michigan.

Tubers: Oblong or elongate-flattened; skin white or creamy white, occasionally suffused with pink around bud-eye cluster in Early Albino.

Sprouts: Base light rose-purple; tips creamy white or light rose-purple.
Flowers: White.

Group 4—Rose.
Tubers: Roundish oblong to elongate-flattened or spindle-shape flattened; skin, flesh-colored or pink, or (in the case of the White Rose) white.
Sprouts: Base and internodes creamy white to deep rose-lilac; leaf scales and tips cream to rose-lilac.
Flowers: White in sections 1 and 2; rose-lilac in section 3.

Group 5—Early Ohio.
Tubers: Round, oblong, or ovoid; skin, flesh-colored or light pink, with numerous small, raised, russet dots.
Sprouts: Base, leaf scales, and tips more or less deeply suffused with carmine-lilac to violet-lilac or magenta.
Flowers: White.

Group 6—Hebron.
Tubers: Elongated, somewhat flattened, sometimes spindle-shaped; skin creamy white, more or less clouded with flesh-color or light pink.
Sprouts: Base creamy white to light-lilac; leaf scales and tips pure mauve to magenta, but color sometimes absent.
Flowers: White.

Group 7—Burbank.
Tubers: Long, cylindrical to somewhat flattened, inclined to be slightly spindle shaped; skin white to light creamy white, smooth and glistening or deep russet in the case of section 2.
Sprouts: Base creamy white or faintly tinged with magenta; leaf scales and tips usually lightly tinged with magenta.
Flowers: White.

Group 8—Green Mountain.
Tubers: Moderately to distinctly oblong, usually broad, flattened; skin a dull creamy or light russet color, frequently having russet-brown splashes toward the seed end.
Sprouts: Section 1; base, leaf scales, and tips creamy white: Section 2; base usually white, occasionally tinged with magenta; leaf scales and tips tinged with lilac to magenta.
Flowers: White.

Group 9—Rural.
Tubers: Broadly round-flattened to short oblong, or distinctly oblong-flattened; skin creamy white, or deep russet in the case of section 2.
Sprouts: Base dull white; leaf scales and tips violet-purple to pansy-violet.
Flowers: Central portion of corrolla deep violet, with the purple growing lighter toward the outer portion; five points of corolla white, or nearly so.

Group 10—Pearl.
Tubers: Round-flattened to heart-shape flattened, usually heavily shouldered; skin dull white, dull russet, or brownish-white in section 1 or a deep bluish-purple in section 2.
Sprouts: Section 1; base, leaf scales and tips usually faintly tinged with lilac: Section 2; base, leaf scales, and tips vinous mauve.
Flowers: White.

Group 11—Peachblow.

Tubers: Round to round-flattened or round-oblong; skin creamy white, splashed with crimson or solid pink; eyes usually bright carmine. Includes some early-maturing varieties.

Sprouts: Base, leaf scales, and tips more or less suffused with reddish-violet.

Flowers: Purple.

Each group in the above classification has been named from the variety within the group which most nearly represents the group as a whole and which is considered perhaps most important commercially. Not all of these groups are equally important, the Green Mountain and the Rural being produced extensively throughout the leading potato states, while such groups as the Early Michigan and the Hebron are nowhere very important.

The leading standard varieties, the season of maturity of varieties included and the region of commercial importance of each group are given in Table XL.

Table XL.—Standard Varieties, Region of Production and Season of Maturity of Potato Groups

Group	Standard varieties	Season of maturity of varieties within the group	Principal regions of production
1. Cobbler	Irish Cobbler Early Eureka Potentate Flourball	Early	New England, Middle Atlantic states, Virginia and the Carolinas.
2. Triumph	Bliss Triumph or Stray Beauty Quick Lunch or Noroton Beauty White Triumph	Very early	Gulf states, Oklahoma, Arkansas, New Mexico, Minnesota and Wisconsin.
3. Early Michigan	Early Michigan Early Puritan Early Albino	Early	Not important commercially. Northwestern U. S. mainly.
4. Rose	*Section* 1 Early Rose Early Norther Burpee's Extra Early Early Thorobred Early Vermont Late Rose Evergreen	Early, medium, late and very late	Northeastern U. S. mainly.
	Section 2 Early Manistee Improved Manistee Late Manistee King Spalding's Rose 4 or Pride of the West	Early, medium and late	
	Section 3 New Scotch Rose Seneca Beauty	Medium	

TABLE XL.—STANDARD VARIETIES, REGION OF PRODUCTION AND SEASON OF MATURITY OF POTATO GROUPS—*Continued.*

Group	Standard varieties	Season of maturity of varieties within the group	Principal regions of production
5. Early Ohio	Early Ohio Early Six-weeks Ohio Junior	Very early	Red River Valley of Canada, Minnesota and North Dakota, Montana, Kansas and Nebraska.
6. Hebron	Beauty of Hebron Early Bovee Crown Jewel New Queen	Early and medium	Not commercially important. New England and Middle Atlantic states mainly.
7. Burbank	*Section* 1 Burbank or Burbank Seedling Pride of Multnomah *Section* 2 Russet Burbank California or Colorado Russet Netted Gem	Medium	Pacific Coast and Intermountain states and irrigated lands of the West.
8. Green Mountain	Green Mountain Norcross Carman No. 1 State of Maine Gold Coin Mill's Pride or Mill's Prize Delaware Lincoln White Mountain Ruloff Green Mountain Jr.	Medium	Ontario, Quebec and Maratime provinces of Canada, New England and Middle Atlantic states, Michigan, Wisconsin and Minnesota.
9. Rural	*Section* 1 Rural New Yorker No. 2 Carman No. 3 Sir Walter Raleigh Number 9 Heavyweight Noxall White Giant Million Dollar Dooley *Section* 2 Dibble's Russet Late Petoskey Rural Russet	Late	New York, Pennsylvania, Ohio, Michigan, Wisconsin, Minnesota and Colorado.
10. Pearl	*Section* 1 Pearl or Peerless Peoples *Section* 2 Blue Victor	Medium and late	Colorado, Idaho and adjacent states. Some Peerless on muck in New York.
11. Peachblow	Early Peachblow Jersey Peachblow McCormick Round Pinkeye Lookout Mountain	Early, medium and late	Colorado, Maryland and Virginia.

The choice of a variety for a given locality should be made on the basis of such factors as soil type, average growing season temperature, and market preference. Most of the varieties in each group are similar not only in vine and tuber characters, but also in respect to soil and climatic adaptation and susceptibility to disease. Thus the Green Mountain, the Hebron and the Cobbler groups of varieties require ideal growing conditions of soil and climate and are relatively susceptible to disease while varieties of the Burbank, the Rural and the Peachblow groups are less affected by adverse environment and are more disease-resistant than other groups. In New York where climatic conditions are often favorable to the development of late blight, the Rural group is better adapted to the heavier soils than the Green Mountain. Such soils are more subject to baking under droughty conditions and more conducive to rot in the tubers in wet seasons and under these conditions, the Rural varieties have been found to rot less and to yield more than those of the Green Mountain group. Varieties of the Rural group also blossom and set tubers about ten days to two weeks later than Green Mountain varieties. This difference might easily have a bearing on the comparative influence of weather on tuber setting, between varieties of the two groups.

A variety to be popular on most markets today must have white-skinned tubers with few, shallow eyes and the tubers must be rather short, flat and of high starch content. Colored skinned, deep-eyed elongated tuber varieties are no longer popular except in the case of some early varieties on a few markets.

Most variety tests have been of very limited value because of (1) their short duration, (2) too few strains of the leading varieties concerned, (3) the very limited and local significance of the results and (4) the exaggerated conclusions drawn. Strain tests of the leading standard varieties for a given region are of much more value, in that they assist the grower in locating and the experiment station in developing high-yielding seed stocks.

Relatively little significance attaches to potato variety names. Of most importance, is the choice of a potato type or group adapted to the particular soil, climate and market and thereafter the choice of a high-yielding strain of seed of some standard variety of this type. Whether a strain of seed thus procured will remain profitable, depends upon its care and selection in both field and storage to maintain its yield and to protect it from disease.

Diseases.—The potato is probably subject to more diseases than most other vegetables. Only a few of these, however, are usually very serious in any one section of the country. Those which depend for their prevalence or severity on weather conditions may be serious one year and inconspicuous the next. Other diseases not influenced by weather, may be present in more or less uniform degree every year. Some diseases

are caused by fungi, some by bacteria, some by slime molds and some others are presumed to be non-parasitic. Some attack the foliage only, some the tubers only and some both. The majority of potato troubles present in this country have been introduced from Europe.

A classification of potato diseases on the bases of type, portion of plant directly affected, regions of principal occurence, method of hibernation and principal control methods is given in Table XLI.

TABLE XLI.—A CLASSIFICATION OF POTATO DISEASES

Disease	Type	Portion of plant directly affected	Regions of occurrence in U. S.	Method of hibernation	Control measures
Late blight (*Phytophthora infestans*).	Fungous	Foliage and tubers	Northeastern U. S.	In seed	Bordeaux mixture 5–5–50
Early blight (*Alternaria solani*).	Fungous	Foliage	Southern U. S. and warmer regions	In trash in field	Bordeaux mixture 5–5–50
Fusarium wilt (*Fusarium oxysporum*).	Fungous	Foliage and tubers	General	In seed and soil	Clean seed and crop rotation
Fusarium dry rot (as above).	Fungous	Tubers	General	In seed and soil	Clean seed and crop rotation
Verticillium wilt (*Verticillium alboatrum*).	Fungous	Foliage and tubers	General	In seed and soil	Clean seed and crop rotation
Yellow dwarf.	Fungous	Foliage and tubers	Northeastern U. S. in cooler portions	In soil	Clean seed and crop rotation
Black-leg (*Bacillus phytophthorus*).	Bacterial	Foliage and tubers	Maine and adjacent territory	In seed	Clean seed and seed treatment
Wart (*Synchitrium endobioticum*).	Fungous	Tubers	Mining districts of Penn. mainly	In seed and soil	Long crop rotation and clean seed
Bacterial soft rots.	Bacterial	Tubers	General following blight rot or injury	In seed in storage	Avoid bruising stored tubers
Bacterial wilt (*Bacillus solanacearum*).	Bacterial	Foliage and tubers	Southern U. S. mostly	General	Control insects and eliminate diseased plants
Silver scurf (*Spondylocladium atrovirens*).	Fungous	Tubers	Eastern U. S.	On seed	Clean seed and seed treatment
Rhizoctoniose (*Corticium vagum*).	Fungous	Tubers, new sprouts and base of stems	General	On seed and in soil	Clean seed, crop rotation and seed treatment with corrosive sublimate 4 oz. to 30 gal. water
Common scab (*Actinomyces chromogenus*).	Bacterial	Tubers	General	On seed and in soil	As for rhizoctoniose
Powdery scab (*Spongospora subterranea*).	Slime mold	Tubers	Very slight in New England	On seed and in soil	As for rhizoctoniose
Spindling sprout	Non-parasitic	Sprout growth from tubers	General	Seed	Seed selection and good storage

TABLE XLI.—A CLASSIFICATION OF POTATO DISEASES—*Continued.*

Disease	Type	Portion of plant directly affected	Regions of occurrence in U. S.	Method of hibernatiod	Control measures
Streak	Bacterial	Stems and leaf petioles	General	Not well known	Not well known
Mosaic	Non-parasitic	Foliage	General except in Rural varieties	In seed	Seed from clean fields and aphis control
Curly dwarf	Non-parasitic	Foliage	General except in Rural varieties	In seed	As for mosaic
Leaf-roll	Non-parasitic	Foliage	General	In seed	As for mosaic
Net necrosis	Non-parasitic	Tuber	General	In seed	Clean seed
Tip-burn	Physiological	Leaf tips and margins	General	None	Bordeaux mixture as for blight
Arsenical injury	Physiological	Leaves burned by free arsenic	Where improperly made arsenical sprays used	None	Use excess of lime with arsenical

The more prominent symptoms of and the principal control measures for a few of the most important potato diseases are discussed in the following paragraphs.

LATE BLIGHT (*Phytophthora infestans*).—This is probably most serious of all potato diseases. It is most serious in wet seasons, since moist conditions are necessary for the germination and spread of the spores of the causal organism. It attacks the foliage at any point and is not confined to the margins or tips of the leaves as in tip-burn. The latter is very often confused with blight by even experienced growers. Blight-affected areas on the leaves are water-soaked in appearance and usually show a whitish mold around the margin on the under surface. Since the blight organism does not live over in the soil nor on dead tissue, the initial infection is from the seed tuber which shows the disease in the form of a reddish-brown dry rot. Spores from the affected stem may come in contact with new leaf growth and thereafter spread from plant to plant or from field to field by wind, rain or other carriers. Thorough spraying under high pressure every ten days to two weeks with 5–5–50 Bordeaux mixture is necessary to insure complete protection from the disease. It is a mistake not to spray before rains because rain is usually responsible for the infection and spread of the causal organism. Spraying with not less than 150 pounds pressure will insure efficient control. Tubers are rotted from late blight as a result of the spores being washed down through the soil during rainy periods late in the growing season. Ridging is therefore one means of protecting tubers from the blight rot.

RHIZOCTONIOSE (*Corticium vagum*).—This disease is present on the skin of the tuber and is very general in occurrence, but because of its resem-

blance to dried muck or dirt, it is commonly overlooked. Although it does not affect the culinary quality, it is often very serious on seed because when planted with the seed piece, the fungus may so girdle the new sprout as to prevent its reaching the surface of the ground. Late or weak hills, as seen early in the summer, are commonly due to this fungus. Soaking the seed before cutting, for 1½ hours in corrosive sublimate at a strength of 4 ounces to 30 gallons of water will kill the fungus on the tuber. Crop rotation is also recommended.

Common Scab (*Actinomyces chromogenus*).—Although as widespread as any other disease, it affects mainly the marketability of the crop. The irregular shaped, russet lesions in the surface, result in waste and may in severe cases make the tubers almost worthless. This disease is similar to Rhizoctoniose in respect to its method of hibernation and control. Unlike the latter, however, the causal organism is favored by alkaline soil conditions. The use of lime, stable manure or wood ashes on soil soon to be used for potato growing should be avoided.

Wilt (*Fusarium sp.*)—The name Wilt is given to this disease because it causes a rapid wilting or collapse of the plant usually late in the growing season. The fungus enters the roots or stolons and becomes localized in the vascular tissues thereby killing this tissue and eventually stopping further sap flow. The base of the plant dies first with a progressive wilting toward the top. A cross-section of either tuber or base of the stem will usually show the disease in the form of dead tissue in the vascular area. Apparently infection may come either from the soil or from affected seed. In cutting seed, all tubers showing discoloration at the stem end should be discarded.

Black-leg (*Bacillus phytophthorus*).—This disease derives its common name from the fact that the causal bacteria produce a soft black decay on the base of the stem and at the stem end of the tuber. The disease is favored by cool weather and is seldom found outside of Maine and other New England states. It does not appear likely to become serious in the potato states farther south. Like many other bacterial diseases, it spreads by insects and contact in circular areas outward from the initial point of infection in the field. Affected plants first show a yellowing in the upper leaves and later a complete killing of the plant. Seed treatment as for common scab, the use of clean seed from uninfected fields and the early elimination of affected plants in the field are the principal control measures.

Mosaic and Curly Dwarf.—These are probably different phases of a single disease, the latter being no more than an advanced stage of pronounced mosaic. A blotching or mottling of the normally dark green leaf with light green areas often accompanied by more or less crinkling or cupping of the leaf surface are typical symptoms. This and the leaf-roll disease are usually classed as virus or non-parasitic since no definite

causal organism has yet been isolated. Mosaic is carried over to succeeding generations in the seed tuber although the latter shows no evidence of abnormality at any time. By virtue of the abnormal chlorophyll development in the leaves and the reduced leaf area in a mosaic plant, the yield is reduced approximately one-third on the average. Although all standard varieties are susceptible to the disease, it is most common in the Triumph and the Green Mountain groups of varieties and very seldom found in the Rural. Transmission is mainly by the potato aphis, *Macrosiphum solanifolii*, which insect injects the juice of infected plants into healthy plants. Control consists in the use of seed from clean fields, in the control of the aphis and in the use of an isolated seed plot to prevent contamination of seed stock by insects which may migrate from diseased fields.

LEAF-ROLL.—This is a non-parasitic disease so-called because its principal symptom consists in the upward rolling of the lower leaves of the plant. The plant is usually, though not always, smaller than normal, of a paler color, and of an abnormally upright or clumpy habit of growth. The leaves are not only rolled but also unusually thick and leathery due to the accumulation of starch which in a normal plant is translocated down through the stolons for tuber production. A similar rolling of the upper leaves only, on the plant is not a true criterion of the disease. Leaf-roll is even more serious than mosaic in that it reduces the yield on an average by two-thirds. Its mode of transmission, method of hibernation and control are apparently identical with those of mosaic. All standard varieties, however, seem to be equally susceptible to the disease.

Insects.—There are six insects which may be considered important in respect to the extent to which they affect the potato crop. Some of these affect the foliage only, some the tubers only and some both. Only these six are discussed here.

COLORADO POTATO-BEETLE (*Leptinotarsa decemlineata*).—This insect is found throughout this country and Canada and is probably most serious of all potato insects. The adult beetle is oval in outline, about three-eights of an inch long and has ten black stripes running lengthwise over its yellow, hard wing-covers. Being first found in the Rocky Mountain section of Eastern Colorado about 1856, it rapidly travelled eastward reaching the Atlantic Coast about 1874 and Nova Scotia, Canada about 1882. It is a leaf-eating insect, most of the damage being done by the larvae which hatch from clusters of orange-colored eggs deposited on the underside of the leaves. The tubers are not affected except indirectly through a reduction in yield because of a reduction in foliage. The minimum life cycle is about 4 weeks' more than one generation a season being possible. The insect over-winters as the adult beetle in the soil. Control consists in the application to the foliage of

arsenical sprays, the more commonly used of these being Paris green, arsenate of lead and arsenite of soda. Spraying is most efficient if applied immediately after the larvae hatch. Paris green and arsenite of soda will, unless properly diluted with water or Bordeaux mixture, or neutralized with lime, cause injury to the leaves by burning. This is not true of arsenate of lead. The latter is also less subject to washing off of the foliage than the other arsenicals. Paris green is usually applied 1 pound to 50 gallons, while arsenate of lead is applied 4 pounds to 50 gallons of water.

Common Flea-beetle (*Epitrix cucumeris*).—The flea-beetle is probably next in importance to the Colorado potato-beetle, and is also of very general occurrence. The adult is a jet-black, shiny, hard-shelled beetle about one-twentieth of an inch long which eats tiny, round holes through the leaves. In severe cases, the leaves are reduced to a sieve-like structure and the yield of tubers thereby much decreased. The larvae occasionally damage the tubers by mining into them sufficiently to cause what are called pimply potatoes. The flea-beetle over-winters in trash or leaves as an adult, emerges in May or June, and lays its eggs near the roots of the plant. There is usually but one brood in a season. Control consists in thorough spraying with Bordeaux mixture which acts as a repellent.

Leaf-hopper (*Empoasca mali*).—This is a leaf-sucking insect which works mainly on the under surface of the leaves. It is a small, elongated, pale-green insect about ⅛ inch long which hops or flies actively from plant to plant. In dry seasons, it may so suck the plant of its juices as to cause much dead tissue at the margins and tips of the leaves. This form of injury is commonly recognized as tip-burn or hopper-burn. It passes the winter in either the adult or the egg form. The nymphs from the winter eggs, appear early in the spring and begin feeding at once. There may be from two to five broods in a season. The only effective control yet devised is the use of Bordeaux mixture as a repellent. Spraying of both upper and lower surfaces of the leaves is absolutely essential. The addition of nicotine sulfate to the regular Bordeaux formula has resulted in quicker control, but the added cost of the nicotine sulfate may not be justified (Dudley 39).

Potato Aphis (*Macrosiphum solanifolii*).—This insect has become a serious potato insect in certain potato-growing areas in recent years. It is a relatively large plant-louse occurring in either pink or green body color and in both winged and wingless forms. As a sucking insect like the leaf-hopper, it works on the under surface of the leaves and on the more tender stem portions of the plant. As the injury progresses, the leaves tend to curl downward and both stems and leaves show irregular, brownish areas from which the juice has been sucked. In dry seasons large circular areas in fields and sometimes whole fields may be prema-

turely killed by this insect. Patch (114) has furnished evidence that the rose is the primary host plant on which the aphis lays its over-wintering eggs and on which the first generation from these eggs in the spring feed. Part of this generation is wingless and part winged, the winged individuals fly to the potato fields during June or July, after which other generations develop rapidly. Serious losses result in potato yields not only from direct injury to the plant, but also from the fact that potato mosaic is mainly disseminated from diseased to healthy plants by this insect. The aphis is difficult of control first, because it works mainly on the underside of the leaves and second, because its presence is usually not detected until damage has resulted and it has become well established. Spraying with nicotine sulfate or "black-leaf 40" as a contact spray and the elimination of wild rose bushes in the locality are recommended.

White Grub (*Lachnosterna species*).—The white grub commonly called June-bug or May-beetle, annually causes considerable loss by the larvae so eating the surface of the tubers as to decrease their market value. In severe cases only, potato plants may collapse because of injury to the roots, stolons or bases of the stems. The insect is most common in fields which for several years previous have been in sod. The larvae feed mostly on grass roots and when these are not nearby they attack the potato tubers. The life cycle is 2 to 3 years, the larva usually requiring 2 years to become full-grown. Tuber injury is done mainly by the larvae in their second year. Although white grubs are abundant about every 3 years, predictions as to when grub years will occur are not always reliable. The years 1921 and 1924 are so-called grub years, much damage being reported for 1921 in Iowa, Minnesota, New York, Connecticut and New Jersey (Ball and Walter, 8). When it is feasible to use old sod land for potatoes, it should be fall plowed in order that the grubs and the beetles may be killed by winter freezing. Otherwise, some crop other than potatoes should follow sod.

Wire-worms.—The adults of the wire-worms are several of the common click-beetles and are probably as common and even more serious than the white grub. The larvae, so-called wire-worms because of their long, hard, cylindrical bodies, eat their way often entirely through the tuber and thus renders it worthless for human consumption. The life cycle is from 3 to 5 years, the larvae requiring somewhat longer to mature than the white grub. It varies in length from ¼ inch to 1 inch depending mostly upon its age. Its habitat and methods of control are identical with those given for white grubs.

Harvesting.—Except in the northernmost sections of the northern potato states, the main crop is not dug until the tubers are mature. Due to the short growing season in Aroostook County, Maine and in some other northern sections, the foliage is usually killed by frost before

maturity. The immature tubers from these sections as well as tubers from the early crop in some other states can be recognized in the market by their peeled, chafed and curled skins. Although this immaturity is considered desirable in seed potatoes, it is less desirable from the standpoint of eating quality. Since yield increases rapidly during the last stages of maturing, the crop should ordinarily not be dug until the foliage is entirely mature. The only exception to this rule is in the event that early market prices are so attractive as to make a certain amount of sacrifice in yield feasible. The rate of increase in yield at various periods up to complete maturity is well illustrated in the results obtained by Kohler (85) as shown in Table XLII.

Table XLII.—Results from Digging Early Ohio Potatoes at Intervals during the Period of Development at the Minnesota Station (1909)

Date of digging	Gain in bu. of marketable per day	Yield in bu. per acre		Per cent of foliage dead
		Marketable	Total	
July 31	...	10.9	38.7	0
August 7	7.5	62.3	87.7	1
August 14	7.6	115.4	141.5	8
August 23	7.2	182.1	203.2	22
August 30	6.4	226.8	253.8	99

Weather plays an important part in determining time of harvest because it is desirable from the standpoint of disease and keeping quality that the tubers go into storage in a clean, dry condition. Digging the crop before maturity in order to avoid tuber rot when the late blight has appeared is a serious mistake. Tubers so dug, are brought in contact with the active blight organism on the foliage and will almost surely rot worse in storage than if they had remained in the soil until all green foliage was dead. Potato tubers keep better and bruise and peel less if allowed to remain on the ground after digging for an hour or two until the skin "sets."

Although much of the crop is still dug by hand, chain-elevator diggers are becoming common wherever topography is not too rolling and stones not too numerous to prevent the use of the machine. Such machines permit of harvesting from three to five times more acreage in a day than is possible with hand digging. With either hand or machine digging, a certain amount of bruising seems unavoidable.

Potatoes are most commonly picked up by hand into slatted crates of one bushel capacity, these being hauled to storage and stored in this way or else dumped into piles. In some sections, hamper baskets are used

instead of crates, the former being used for trucking to market or for dumping direct into barrels or wagon boxes.

Grading.—Since it is much easier to judge appearance than eating quality in market potatoes, appearance is the more influential factor in price determination. The advantage of some system of uniform grading both as to size of tuber and skin character is therefore obvious. Although relatively little grading is yet done, it is annually becoming more common. Growers are slowly beginning to realize that it does not pay to ship and pay freight on ungraded stock containing dirty and undersized and misshapen tubers. Such stock is eventually graded before it reaches the consumer and, as a result, the handling costs deducted by the middlemen are greater, the growers' receipts less and the consumers' cost more. In addition the cull stock removed in the grading process is wasted, whereas it would have some value as stock feed if left on the farm.

Standard grades for potatoes were recommended by the United States Department of Agriculture and the United States Food Administration in 1917. These grades were made mandatory by the Food Administration from January to December in 1918. These grades have become sufficiently popular that many growers are voluntarily using them and many states have established them as their official standards. These grades as revised since 1918 are as follows:

U. S. No. 1 shall consist of potatoes of similar varietal characteristics which are not badly misshapen, which are free from freezing injury and soft rot, and from damage caused by dirt or other foreign matter, sunburn, second growth, growth cracks, hollow-heart, cuts, scab, blight, dry rot, disease, insects, or mechanical or other means.

The diameter of potatoes of round varieties shall be not less than 1⅞ inches and of potatoes of long varieties 1¾ inches.

In order to allow for variations incident to proper grading and handling, not more than 5 per cent, by weight, of any lot may be below the prescribed size, and, in addition, not more than 6 per cent, by weight, may be below the remaining requirements of this grade, but not to exceed one-third of this 6 per cent tolerance shall be allowed for potatoes affected by soft rot.

U. S. No. 1 Small shall consist of potatoes ranging in size from 1½ to 1⅞ inches in diameter but meeting all the other requirements of U. S. No. 1.

In order to allow for variations incident to proper grading and handling not more than 25 per cent, by weight, of any lot may vary from the prescribed size, but not to exceed one-fifth of this tolerance shall be allowed for potatoes under 1½ inches in diameter. In addition not more than 6 per cent, by weight, may be below the remaining requirements of this grade, but not to exceed one-third of this 6 per cent tolerance shall be allowed for potatoes affected by soft rot.

U. S. No. 2 shall consist of potatoes of similar varietal characteristics which are free from freezing injury and soft rot and from serious damage caused by sunburn, cuts, scab, blight, dry rot, disease, insects, or mechanical or other means.

The diameter of potatoes of this grade shall be not less than 1½ inches.

In order to allow for variations incident to proper grading and handling, not more than 5 per cent, by weight, of any lot may be below the prescribed size, and, in addition not more than 6 per cent by weight, may be below the remaining requirements of this grade, but not to exceed one-third of this 6 per cent tolerance shall be allowed for potatoes affected by soft rot.

U. S. Fancy No. 1 shall consist of potatoes of one variety which are mature, bright, well shaped, free from freezing injury, soft rot, dirt or other foreign matter, sunburn, second growth, growth cracks, hollow-heart, cuts, scab, blight, dry rot, disease, insect or mechanical injury, and other defects. The range in size shall be stated in terms of minimum and maximum diameters or weight following the grade name, but in no case shall the diameter be less than 2 inches.

In order to allow for variations incident to proper grading and handling, not more than 5 per cent, by weight, of any lot may vary from the range and size stated and, in addition, not more than 6 per cent, by weight, of any lot may be below the remaining requirements of this grade, but not to exceed one-third of this 6 per cent tolerance shall be allowed for potatoes affected by soft rot.

Storing.—Some of the influences of temperature, humidity and aeration on stored seed potatoes have been discussed in a previous paragraph. Statistics show that about one-half of the potato crop of the United States is annually in storage on January first. Approximately one-fourth of this amount is held by dealers, the remainder by the producer. All this indicates the importance of storage facilities. The average house cellar is too warm and too poorly ventilated for ideal storage. As a result, the respiration rate from stored tubers is increased, the rest period is prematurely broken and the stored crop is removed in the spring in a badly sprouted and shrunken condition. Clark (25), storing potatoes under controlled temperatures approximating 34 to 40 degrees F. from November to March during 1915, 1916 and 1918, recorded an average total shrinkage ranging from 7.0 to 7.8 per cent. About one-half or 3.6 per cent of this loss was due to dirt removed during the handling and grading processes. When the crop is stored in large piles on the cellar bottom instead of in slatted bins or in crates, the temperature may rise so high and the aeration may be so poor as to cause physiological injury to the tubers at the bottom and center of the pile. This form of injury has been termed "black-heart" by Stewart and Mix (143) who, in a series of cylinder experiments, determined that it is unsafe to pile potatoes deeper than three feet at temperatures above 50 degrees F. and that 6 feet should be the maximum depth when the temperature is to be maintained below 45 degrees F. for several months.

Such storage factors as cost of labor, insurance on buildings, shrinkage, taxes and interest on investment in the stored crop must always be taken into account. Whether to store or market the crop at

harvest time should be determined by an estimate of whether or not prices are likely to increase or decline from fall until spring. Prices have usually increased toward spring in years of sub-normal production and decreased in years of over-production of the crop in the United States.

Marketing.—This may be both local and inter-state. Early potatoes from Florida begin to go into northern markets in April, Carolina potatoes in May, Virginia potatoes in June and New Jersey and Long Island potatoes in July and August. The late or main crop varieties are found in the leading markets from September to April.

Various marketing facilities are in use, the agency depending upon such factors as distance to cities, highway and railroad facilities, and the development of local or state cooperative selling organizations. Most of the crop is still sold by the producer to local track-side dealers who accept and store the crop in limited quantities in warehouses as the roads and markets warrant. From the local dealers, the crop often goes to commission merchants, then to brokers, then to wholesalers and finally to the retailers. The number of marketing steps between the producer and the consumer is the principal factor influencing cost of marketing. Many local, county and state producers' cooperative selling organizations have come into existence during the last few years.

Although more potatoes are still shipped in bulk than any other way, bag containers are becoming more popular. Bag shipments result in less damage and shrinkage in marketing and as a result return the grower a larger per cent of profit. Burlap bags of 100 to 120 pounds capacity are commonly used west of the Mississippi River while the 150- and the 165-pound sizes are more common in the East. Maine, Virginia and Florida potatoes have been shipped principally in barrels of 11- and 12-pecks capacity. Growers in these states are now using bags more commonly than heretofore. Barrel and hamper containers are objectionable because of expense and breakage. The average carload of potatoes contains 600 to 700 bushels.

Improvement.—As long as most potatoes in this country are grown and stored under temperatures too warm to be ideal and as long as such non-parasitic diseases as leaf-roll and mosaic are prevalent, seed stock will tend to degenerate. Consequently, a certain amount of continuous effort for improvement is necessary. Since the potato is propagated asexually by tuber cuttings improvement is accomplished mainly by what may be termed *clonal selection*. Clonal selection is, in turn, based upon the fact of variation between strains within the variety, between hills within the strain and between tubers within the hill. Thus the principal methods of improvement by seed selection have been termed (1) mass selection, (2) mass-hill selection, (3) pedigree-hill selection and (4) tuber-unit selection. All these aim to accomplish improvement by increasing yield and by decreasing or eliminating disease. Of the above

methods, the first is the least thorough and the slowest of results, the last the most thorough and the most expeditious.

In *mass selection*, tubers of ideal appearance are selected from the bin or mass for planting without regard to the yielding ability or health of the parent plant. Although this is a common practice, only a slight improvement may be expected from it. It is not possible to detect non-parasitic diseases nor yielding ability by the appearance of tubers.

Both *mass-hill* and *pedigree-hill selection* consist first of all in the selection during the growing season of healthy, high-yielding hills. This provides for the avoidance of non-parasitic diseases evident in the foliage and the choice at harvest time of the highest yielding hills. Hills so selected are used in planting a seed plat the following year. In *mass-hill* selection, all selected hills are thrown together and planted without regard to the future performance of each individual hill. Planting selected hills, each in a row by itself for further study and record, as in *pedigree-hill selection*, provides for the later elimination of such hill progenies as do not maintain the high yielding ability of the parent hill.

Inasmuch as tubers within the hill vary just as hills within the strain, so selection of individual tubers for test, as in *tuber-unit selection*, provides for the saving of seed from the progeny of only such units as maintain desirable characters. A so-called tuber unit usually consists of the four hills planted from the seed cut from a single selected tuber. None of these methods require the annual selection of hills from the main field. After the original selections are made, all further efforts are confined to the seed plat.

In recent years, growers' organizations for the inspection and certification of seed potatoes have developed. Certified seed is seed which is certified to be practically free from disease, and varietal mixture, to be reasonably true to type and to be high yielding as based upon a certain number of field and bin inspections. Such seed has supposedly met a published standard of excellence. Copy of the exact record of condition in field and bin is usually made available to the trade. Seed inspection and certification aim primarily to accommodate the demand for seed of known qualities under limited guarantee.

SWEET POTATO

The sweet potato is a very important crop in tropical and subtropical countries, as in Africa, India, China, Japan, the Malyan Archipelago, the Pacific Islands, tropical America and southern United States. In fact in the South it is of more importance and partially takes the place of the Irish potato in the diet. The sweet potato is often called "potato"

in the South and the potato is called "Irish potato" or "white potato." It is a standard food article in the South, being served baked, fried, candied and used as filling for pies.

Some varieties of sweet potatoes, especially those having a moist, soft texture when cooked, are often called "yams" to distinguish them from the dry-fleshed varieties. It is unfortunate that the term "Yam" has been used in connection with the sweet potato since the true yam is an entirely different plant, belonging to the genus Dioscorea. Those two plants are not even closely related.

Statistics of Production.—The sweet potato ranks next to the Irish potato in importance as a commercial truck crop. In 1919 the area of sweet potatoes harvested was 803,727 acres, and the production was 78,091,913 bushels valued at $124,844,475. The average yield per acre for the entire country was 97.2 bushels and the average value per acre was $155. Nearly 22 per cent of the farms in the United States reported sweet potatoes. In the South Atlantic states 46.9 per cent of the farms reported sweet potatoes and in the East South Central division 41.2 per cent. Eight states, Georgia, Alabama, North Carolina, Mississippi,

Table XLIII.—Acreage, Production and Value of Sweet Potatoes in Important Producing States, 1919

State	Acres	Production, bu.	Value	Average Yield per acre	Average value per acre
Georgia	110,033	10,132,016	$ 13,171,629	92.1	$120
Alabama	90,868	8,095,404	11,333,568	89.1	125
North Carolina	74,678	7,959,786	11,939,707	106.6	160
Mississippi	69,394	6,550,500	9,170,687	94.4	132
Virginia	42,889	5,981,348	9,570,164	139.5	223
Texas	68,142	5,838,879	10,509,980	85.7	154
South Carolina	60,325	5,369,611	8,591,379	89.0	142
Louisiana	68,033	5,324,419	8,785,292	78.3	129
Tennessee	39,645	4,452,883	7,347,259	112.3	185
Arkansas	39,019	3,959,870	6,533,789	101.5	167
Florida	26,436	2,460,872	3,445,221	93.1	130
Oklahoma	16,735	1,844,463	3,504,490	110.2	209
New Jersey	15,427	1,772,829	3,634,301	114.9	236
Delaware	9,813	1,505,278	2,634,237	153.4	268
Maryland	10,185	1,453,880	2,762,373	142.7	271
Kentucky	14,892	1,222,651	2,750,979	82.1	185
Missouri	11,165	997,606	2,094,979	89.4	188
California	7,632	867,300	1,994,790	113.6	261
Illinois	8,003	668,845	1,337,690	83.6	167
United States	803,727	78,091,913	124,844,475	97.2	155

Virginia, Texas, South Carolina and Louisiana produced 70.8 of the entire crop in 1919. Over 90 per cent of the crop was produced in the fifteen states comprising the South Atlantic, East South Central and West South Central groups of states. The acreage, production, value, average yield per acre and average value per acre of sweet potatoes in these fifteen states and in New Jersey, Missouri, California and Illinois are given in Table XLIII.

In addition to the states listed the sweet potato is grown commercially to a limited extent in West Virginia, Pennsylvania, southern Ohio, southern Indiana, in Iowa especially in the vicinity of Muscatine, in Kansas mainly in the Kaw River Valley, in New Mexico and Arizona. It is grown for home use in all of the states mentioned and in several others.

History and Taxonomy.—The sweet potato is probably a native of tropical America and was carried to the islands of the Pacific very early. It was apparently known in China early in the Christian Era. It was probably cultivated by the natives on the American continent hundreds, or perhaps thousands of years before the discovery of America by Columbus. Many varieties were in existence at the time America was discovered. It was mentioned by Oviedo (1526) as being grown in the West Indies and was carried by him to Spain. It was known in Virginia in 1650 and possibly earlier. It is now widely distributed and important throughout the world where the climatic conditions are favorable.

The sweet potato (*Ipomoea batatas* Poir.) belongs to the Convolvulaceae or morning-glory family. It is a tuberous-rooted perennial. The stems are usually prostrate and slender, and the juice of both vines and roots milky. The blossoms resemble those of the common morning-glory, being almost white, or pale violet in color.

Climatic Requirements.—The sweet potato plant is tender, and requires a long, warm growing season for profitable growth. It cannot be grown successfully in a region having less than 4 months' frost-free period, with warm weather and sunshine for a greater portion of this period. Even with 4 months' growing season the sweet potato does not produce a satisfactory yield unless the nights, as well as the days, are warm for a considerable portion of the time.

The sweet potato is one of the most drought-resistant vegetables. In fact it will produce a fair crop without irrigation in semi-arid regions, where most vegetable crops will not thrive at all. A moderate rainfall during the growing season is, however, desirable. In regions of scant rainfall irrigation is profitable, when the water is applied at the right time. Most of the water should be applied between the time the plants are set and the time when they practically cover the ground. Garcia (51) reports that six to ten irrigations at the Experiment Station in New Mexico have produced good yields. He states further that if the sweet

potatoes are kept well irrigated and the surface soil moist the tubers are nearer the surface of the ground than if the surface soil is allowed to dry out too much. Light irrigations at frequent intervals are preferable to heavy irrigations at long intervals.

Soils.—A well-drained, sandy loam soil with a clay sub-soil is considered ideal for sweet potatoes, although the crop can be grown on a wide range of soils if the growing season is sufficiently long. They are sometimes grown on almost pure sand, and with a fair amount of fertilizer, good yields are obtained. On very rich soils the crop produces too much vine growth and the potatoes are likely to be too large and rough, which reduces their market value. On heavy clay soils the tubers are also likely to be rough and irregular in shape. It is best, therefore, to select a light, moderately rich soil. The crop is particularly adapted to the newly cleared lands, such as the cut-over pine lands of the South.

Good drainage is important in growing sweet potatoes since the crop does not do well when water stands around the plants. Planting on ridges is commonly practiced on much of the land in the South, mainly for the purpose of drainage.

Preparation of the Soil.—On deep soils there is a tendency for the roots to grow long and slender, therefore, deep plowing is not advocated. However, a depth of 6 to 8 inches is none too deep and is much better than 3 to 4 inches, which is the common depth of plowing on so many southern farms. After plowing the soil should be thoroughly prepared as for other crops. Because the sweet potato will produce a fair crop with poor preparation too little attention is given to preparing the land for this crop.

On a large part of the farms growing sweet potatoes the plants are set on ridges. These ridges are usually thrown up with a small plow, throwing two furrows together. The ridges should be as low and flat as the drainage conditions will allow since narrow, sharp ridges dry out more readily than wide, flat ones.

Starnes (141) reports experiments in which a comparison of ridge and level culture was made. In 1893 plants grown on ridges 14 inches high produced at the rate of 272.75 bushels and those grown on the level 237 bushels to the acre. In 1894 the results were practically reversed. Under level culture the yield was 270.3 bushels and under ridge culture 237.2 bushels to the acre. Commenting on these results he has the following to say:

> Unquestionably, results under this head depend upon the season. In a wet season, or in one with even a full sufficiency of moisture, ridging will be found to pay, even taking into consideration the extra cost of the hoe work necessary. In a dry season, or in one with even a slight insufficiency of rain, level culture will be found preferable. . . .

Unfortunately Starnes does not state the character of the soil on which the experiment was conducted. The results on a sandy, or sandy loam

soil would undoubtedly be very different from those secured on a clay soil. On the former level culture would show to much greater advantage than on the latter. Experiments at the Arkansas Experiment Station on a deep, level, well-drained, rich sandy soil gave results in favor of ridges 3 inches high, as compared with level culture and with ridges 6 and 9 inches high.

Manures and Fertilizers.—Commercial fertilizers are commonly used in growing sweet potatoes since satisfactory yields are produced by their use. As the sweet potato gives better results than most other vegetable crops on soils deficient in humus manure can be used to better advantage on other crops. Fresh manure causes a rank growth of vines and the development of large, rough roots. It seems best, therefore, to apply manure to other crops and to depend on fertilizers to furnish the elements that are needed for the sweet potato crop. Durst (40) reports results of 4 years' experiments on a yellow silt loam soil in southern Illinois, which are favorable to manure. Eight plats were used and were given the following treatments per acre:

Plat 1. Check (no fertilizer).

Plat 2. 660 pounds fertilizer, consisting of 2 parts steamed bone (12½ per cent P_2O_5), 2 parts dried blood (14 per cent N) and 1 part K_2SO_4. Applied broadcast.

Plat 3. 10.56 tons manure broadcast.

Plat 4. 528 pounds steamed bone broadcast.

Plat 5. Check.

Plat 6. Same as plat 2, except applied under ridge.

Plat 7. 10.56 tons manure under ridge.

Plat 8. 528 pounds steamed bone under ridge.

The average yield of table and seed potatoes per acre and the gross and net value of the crop under the various treatments are given in Table XLIV.

TABLE XLIV.—YIELDS AND RETURNS FROM SWEET POTATOES UNDER VARIOUS FERTILIZER TREATMENTS

(Adapted from Ill. *Bull.* 188)

Plat	Yield bu. per acre	Gross value	Value less cost of fertilizer
1	111.23	$ 83.43	$ 83.43
2	127.76	95.62	83.08
3	140.23	105.18	89.34
4	123.06	92.31	85.71
5	111.00	83.25	83.25
6	132.40	99.31	86.77
7	159.07	119.31	103.47
8	134.17	100.63	94.03

Examination of the table shows that the manure applied under the ridge produced the highest yield and the highest net return, but the cost of hauling and applying the manure is not taken into consideration. The price, $1.50 per ton, is too low for manure, especially considering the cost of hauling. The manure supplied nearly three times as much nitrogen and about 50 per cent more potash than the fertilizers used on plats 2 and 6. The phosphorus was nearly equal in the two treatments.

As the result of experiments on a clay soil in Georgia, Starnes (141) recommended a fertilizer containing 320 pounds acid phosphate (14 per cent), 360 pounds cottonseed meal and 640 pounds kainit. Muriate of potash at the rate of 80 pounds to the acre in combination with the acid phosphate and cottonseed meal produced practically the same yields.

Where the sweet potato is grown as a general farm crop in the South cottonseed meal and acid phosphate are commonly mixed together and applied at the rate of 500 to 600 pounds to the acre. Some growers mix them in equal proportions, while others use 1 part of the former to 2 or 3 parts of the latter. On sandy soils some potash would probably increase the yield. Sweet potatoes grown as a truck crop are usually more heavily fertilized than when grown as a general farm crop. Applications of 1,000 to 1,500 pounds to the acre of a 2–8–6, 2–8–8 or 3–8–8 is not uncommon and on the average sandy or sandy loam soil the lower amount is certainly none too high. As much as a ton is sometimes used.

In some sections of the South sweet potatoes follow a crop of early Irish potatoes. The latter are usually heavily fertilized with a high-grade mixture and no additional fertilizer is applied for the sweet potatoes.

Fertilizers are applied broadcast or in the row. Where the application is 500 to 750 pounds to the acre applying in the row is probably preferable, but for 1,000 pounds or more broadcasting should be the method followed. Heavy applications in the row may cause injury by burning the plants. Fertilizer drills may be used for either broadcast or row applications. When the row method is used the material is applied in a furrow and the ridge is made over it.

Propagation.—Sweet potatoes are grown either from plants or slips produced from roots, or from cuttings of the vines. In the northern sweet potato sections a large part of the crop is grown from slips produced from sprouting seed potatoes in a hotbed. In the regions south of Virginia the early crop for market is produced from slips, but a large part of the main crop is grown from vine cuttings. In this case enough roots are bedded, in an open bed, to produce slips for about one-eighth of the area to be planted. These slips are planted in the usual manner, and when the vines begin to run cuttings are taken to plant the remainder of the field.

The growing season in the northern part of the sweet-potato region is too short for producing a commercial crop from vine cuttings, but this

method is often used to grow seed roots for the following year. The vine cuttings have the advantage of being free from some of the serious diseases which are carried from the seed bed to the field on the slips. In the South, where the growing season is long, vine cuttings are preferable to slips for the main crop. The vine cuttings are cheaper, produce roots more nearly uniform in size and shape and are less likely to carry disease. Experiments show that the yield from vine cuttings is as large, or even larger than from slips planted at the same time. In an experiment in Georgia (154) the yield was much larger from vine cuttings then from slips set July 28, 1913. In Arkansas the yields from slips and from vine cuttings were practically the same. In experiments conducted for two years the yields from slips and from vine cuttings were as follows:

Slips, average 134.75 bushels per acre.
Cuttings, average 139.25 bushels per acre.

The percentage of marketable potatoes was slightly greater from cuttings than from slips.

Growing the Plants.—When slips alone are used 6 to 8 bushels of seed roots are required to produce enough plants from the first pulling to set an acre, but if sufficient time is available to make two or three pullings 3 to 4 bushels of seed ordinarily will produce slips enough for an acre. The amount of seed required depends upon the size of the roots and the distance between the plants in the field. Large roots produce fewer plants from a bushel of seed than small or medium sized roots. One bushel of good seed roots will produce 2,500 to 3,000 plants from two or three pullings, and should be given 20 to 24 square feet of bed space. Before bedding the seed roots should be disinfected by treating for 5 to 10 minutes in a solution made by dissolving one ounce of corrosive sublimate in 8 gallons of water. After disinfection the potatoes should be rinsed in clean water and placed in the sun to dry. This treatment will not kill the fungus within the potato, but will destroy any spores that may be on the surface. The solution should not be used more than two or three times since it loses its effectiveness after repeated use.

Open beds are usually made in a protected location, such as on the south side of a building or tight fence. The drainage should be away from the bed. An excavation is made 6 to 12 inches deep, 5 to 6 feet wide and as long as needed for the quantity of potatoes to be bedded. Manure is sometimes used to furnish a little heat to start the sprouts and in this case a depth of 12 inches is none too much. If manure is not used a depth of 6 inches is sufficient. About 4 inches of sand or loose soil is placed over the manure or on the bottom of the bed and leveled. The potatoes are then placed by hand as close together as practicable without allowing them to touch. They are then covered to the depth of an inch or two with sand or soil. The bed is watered thoroughly by sprinkling

with a hose or watering can. As soon as the plants come through the surface more sand or soil is added, in order to develop a good root system. Straw, hay, leaves or other litter is sometimes placed on the bed to prevent rapid drying of the surface and to protect it from cold. This covering should be removed as soon as the plants break through the surface of the soil to avoid soft, tender growth.

Hotbeds are used for growing sweet potato plants in the North and for a very early crop in sections of the South. All methods of heating are used including the use of manure, steam, hot water and hot air. The flue-heated hotbeds are the most common, especially in those regions where hotbeds are not employed for growing other plants. The methods of construction and management of hotbeds are discussed in Chapter VII.

The temperature of the soil in the hotbed should be 80 or 85 degrees F. at the time the seed is bedded and should fall gradually until it reaches 70 or 75 degrees F. A high temperature favors rapid, soft growth and a low temperature delays sprouting and may even prevent it completely. At the proper temperature 6 weeks is sufficient time to grow plants large enough for setting out.

As soon as the potatoes are bedded and covered with soil the bed should be watered. Later waterings should be given as needed. More water is required when steam, hot water, or furnace heat is used than when manure is used to supply heat. After the plants are up and the beds are left uncovered during the day frequent watering is necessary.

Planting.—The sweet potato plant is tender and will not withstand a frost, therefore, planting should be delayed until the danger of frost is past. In regions having a relatively short growing period it is advisable to set the plants as early as weather conditions will allow. For an early crop in the South early planting is also desirable. For the main crop in most sections of the South planting in May and June usually gives better results than earlier planting. Experiments by Stuckey in Georgia (154) with the Pumpkin Yam variety show the heaviest yield from June 11 planting one year, May 16 the next year and May 20 2 years later. In some regions vine cuttings are planted in July and even as late as the first part of August with satisfactory results. Good yields need not be expected with less than 4 months' growing season after setting the plants.

With hand planting it is desirable to set the plants when the soil is wet so as to avoid the extra labor and expense of applying water. If the soil is dry when the plants are set water should be used if at all practicable. If watering is not practicable the plants should at least be dipped in a thin paste made with mud and water to prevent the roots drying out before being set and to make the soil adhere to them. This is called "puddling," and is usually done as the plants are pulled from the bed. The paste should not be allowed to dry on the roots as this would prevent the roots from coming into contact with the soil and delay growth.

After puddling the roots the plants should be kept covered with burlap, old carpets, blankets, hay, straw or material which is kept moist.

The spacing of sweet potato plants varies between wide limits depending upon the variety and the richness of the soil. Varieties which produce long vines are given more space than those with short vine growth and on a rich soil more space is usually given than on a poor one. For varieties producing medium to long growing vines the rows are spaced 4 to 6 feet apart and the plants are set 12 to 18 inches apart in the row, 15 inches being a common distance. Varieties producing short vines are planted in rows 3 to 4 feet apart in most regions. On the Eastern Shore of Virginia and in some other regions the plants are set 16 to 22 inches apart in rows about 30 inches apart for the Yellow Jersey variety. Sometimes when the plants are set 22 inches apart in the row two slips are set in each hill. In New Jersey the rows are spaced 2½ to 3 feet apart with the plants 22 to 30 inches apart in the row for cultivating both ways. If cultivation is to be in only one direction the plants are spaced 18 to 25 inches apart in the row. Experiments in Louisiana for 3 years resulted in favor of setting the plants 18 inches apart. The yields of merchantable potatoes per acre was 252 bushels for 8-inch spacing, 258.31 for 12 inches, 275 for 15 inches, 281.82 for 18 inches. Experiments in Georgia for 1 year showed a larger yield for plants set 18 inches apart than for those set either 24 or 30 inches apart. In the Georgia experiment the Southern Queen and Pumpkin Yam varieties were used.

Sweet potato plants are set by hand or by transplanting machinery. When planted by hand the various methods described in Chapter IX are used. Wooden tongs with which the plant can be caught by the root and thrust into the soil, are used by some growers. The tongs cannot be used alone to good advantage unless the soil is well prepared and is loose at the time of setting. An implement known as a "shovel" consisting of a piece of lath sharpened to a flat point, is sometimes used in connection with the tongs. This is used to open the hole for the plant. The operator carries the tongs in the left hand and the shovel in the right. Vine cuttings are usually pressed into the soil with a long notched stick. The cuttings are dropped at the proper distances and the planters place the notch of the stick over the middle of the cutting and force it into the soil to the depth of 3 or 4 inches. With any of the hand methods of setting plants or cuttings it is important to pack the soil around them to prevent rapid drying.

Cultivation.—The methods of cultivating sweet potatoes are not very different from those employed with other farm crops. In a large part of the South they receive less cultivation than most other vegetables and in many instances less than cotton and corn. They should, however, be cultivated often enough to keep the weeds under control and to prevent a hard crust from forming on the soil. Cultivation is done with one-horse

cultivators, sweeps, or with gang cultivators drawn by two horses. As a rule the soil is worked toward the row to widen the ridge. Cultivation should be continued until the vines meet in the middles, but after this no attention is needed except to pull the large weeds by hand.

Difference of opinion exists regarding the advisability of moving the vines so that cultivation can be continued late in the season. Many growers turn the vines first to one side of the row and then to the other while cultivation is going on. Experiments by Starnes in Georgia (141) indicate that disturbing the vines reduces the yield. The yield of sweet potatoes of the Pumpkin Yam variety was 270.3 bushels to the acre from plants not disturbed while only 156.3 bushels were produced from vines which were not allowed to root at the joints. This experiment was conducted for only 1 year hence is not conclusive. Newman in Arkansas (107) conducted similar experiments for 2 years with the following results:

Vines moved for cultivation yielded 166 bushels, while those not moved produced 170.85 bushels per acre. Vines lifted once a week produced 160.50 bushels and those not lifted produced 169.45 bushels per acre. Where the vines were moved for cultivation two more cultivations were given than when they were not disturbed. While the difference in yields from plants not moved and those that were moved is not great, it seems safe to say that disturbing the vines after they have grown to considerable length is not justified and is likely to reduce the yield.

Pruning back the vines has been followed by some growers with the idea that keeping down foliage growth stimulates development of roots. Results of experiments by Garcia (51) in New Mexico and Starnes (141) in Georgia indicate that cutting back the vines materially reduces the yield. In New Mexico the experiments were carried on for 2 years with results as follows: Hills pruned back to 12 inches in diameter produced 6,012 pounds to the acre, those pruned back to 24 inches produced 8,690 pounds, those cut back to 36 inches produced 10,857 pounds while the plants not disturbed produced 16,520 pounds of potatoes to the acre. In Georgia (141) the undisturbed plants produced 201.3 bushels per acre, plants pinched back weekly to 2 feet throughout the season produced 104.9 bushels and those cut back weekly to 2 feet after September 1 produced only 50.1 bushels to the acre. While the experiment in Georgia was carried on for only 1 year the results are so striking that they are worth considering. The very small yield from the plants which were cut back after September 1 may have been due to the fact that only the older leaves were left on the vines after the cutting back. The plants which were cut back throughout the season had undoubtedly developed new vines and new leaves from the older branches and from the main stem of the plant. These new leaves would be much more active than the older leaves on the vines cut back after September 1.

Varieties.—There are at least two hundred names given to the varieties of sweet potatoes grown in the United States, but not over forty true varieties exist. Not over ten varieties are of commercial importance and five of these constitute the bulk of the commercial crop.

Various attempts have been made to classify varieties of sweet potatoes. Price (118) classified them into three groups based on the shape of the leaves. He then described each variety, but as no key was given except that referring to the shape of the leaves it is impossible to determine a variety if the name is doubtful or unknown. Groth (57) worked out a system of classification based on shape of leaf, size of leaf, length of stem, color of stem, size of stem, presence of star, color of lower surface of veins, arrangement of hairs on upper and lower surface of leaves, outside color of tubers, color of flesh and distinctness of wood elements in tuber. This system is a great improvement over the one advanced by Price, but, since some of the characters used vary greatly under different conditions they are not entirely reliable. The terms "size of leaf," "size of stem" and "length of vine" as used by Groth are not reliable characters since the richness of the soil and the weather conditions greatly influence all of these. Some of the varieties described as having short stems (under 4 feet) grow to a length of 6 to 10 feet in nearly all regions where they are grown commercially.

The latest and perhaps the most complete system of classification is that published by Thompson and Beattie (161). Under this system the varieties showing a marked similarity are grouped together in eight well-defined groups, each being distinct and easily recognized. By means of a simple key the group to which any variety belongs can be determined. Each group has been given the name of the most widely known, or the most typical variety. Three of the large groups have been divided into sections to simplify the procedure of identification. The key to the groups is as follows:

I. Leaves deeply lobed or parted (1 and 2).
  1. Leaves with deep purple stain at base of leaf blade—Ticotea group.
  2. Leaves without purple stain at base of leaf blade—Belmont group.

II. Leaves not deeply lobed or parted (1 and 2).
  1. Leaves with purple stain at the base of leaf blade (A and B).
    A. Stems purple or greenish with a decided tinge of purple—Spanish group.
    B. Stems green (*a* and *b*).
      (*a*) Leaves entire to slightly shouldered: roots white—-Shanghai group.
      (*b*) Leaves toothed with six to ten low, marginal teeth, or entire; roots salmon, or yellow tinged with salmon—Florida group.
  2. Leaves without purple stain at the base of the leaf blade (A and B).
    A. Stems purple—Southern Queen group.
    B. Stems green (*a* and *b*).
      (*a*) Stems medium to large in size; roots fusiform, yellow tinged with—salmon with light yellow veins—Pumpkin group.
      (*b*) Stems slender; roots russet-yellow or red, ovoid to fusiform—Jersey group.

In attempting to identify a variety, the group to which it belongs should be determined by means of the key, then the group description should be read and finally the description of the varieties in the group or section of the group in case it is divided into sections. The group description has been made from the descriptions of the varieties belonging to the group and not from any particular variety.

The eight groups and the varieties belonging to them are listed below.

Ticotea Group.—This group contains only two varieties, Ticotea and Koali Sandwitch, and is not important.

Belmont Group.—This is one of the large groups and is divided into two sections as follows:

Vines long creeping—Belmont section.

Vines very short and bushy—Bunch section.

Belmont (also called Georgia and Dunton's Improved), Eclipse Sugar Yam, Vineless Pumpkin Yam, Georgia (Old Time Yam), Yellow Yam and White Sealy belong to the Belmont Section.

Gros Grandia and Bunch Candy Yam (also called Bunch Yam, Vineless, Prolific and Gold Coin) belong to the Bunch section.

Spanish Group.—The varieties in the Spanish group are separated into three sections as follows:

Roots light yellow to russet yellow—Yellow Spanish section.

Roots light yellow tinged more or less with rose, or deep rose—Bermuda section.

Roots dark red to purple—Red Spanish Section.

In the Yellow Spanish section the roots are light yellow in color, usually very irregular, strongly ribbed and veined, but sometimes fairly smooth and regular; flesh white or yellow. The varieties in this section are Pierson (Arkansas Beauty, California Golden, Early General Grant, Golden Skin and Dutton's Beauty), Yellow Strasburg (Extra Early Golden, Adams), Yellow Spanish (Bronzed Spanish), and Triumph.

The roots of the Bermuda section are light yellow, more or less overlaid with transverse dashes and bands of rose, sometimes washed with rose, or deep rose to purple, usually very irregular, strongly ribbed and veined, but some varieties are quite smooth and regular. The varieties belonging to this section are Red Bermuda (Cuba Yam, Poreland, Yellow Red), Red Brazil or Red Brazilian, Porto Rico (Golden Beauty, Key West Yam), Key West Yam and Creola.

Roots of the Red Spanish section are more regular and not so constricted; the flesh is white tinged with purple beneath the skin and at the center. This section contains Red Spanish (Black Spanish), Purple Yam or "Nigger Choker" and Dahomey.

Shanghai Group.—Only two varieties belong to this group Shanghai (Early Golden) and Minnet Yam, and neither is important.

Florida Group.—Three varieties belong to this group, Florida (Arizona Prolific, Providence), General Grant Vineless and Nancy Hall. The Nancy Hall is the most important commercial variety grown in the South. The other two varieties are not important.

Southern Queen Group.—The White Yam and Southern Queen are the only varieties in this group, the latter being one of the best known

varieties of sweet potatoes. It is a good keeper, but is of poor quality until late in the storage season. It is known under the following names: Hayman, California Yam, Arkansas Hybrid, Brazilian, Cuban, Common Yam, Johnson's Bahama, Archer's Hybrid, Hamburg, Caroline Lee, Cullman Cream, Catawba White, Catawba Yellow and Ballinger's Pride.

Pumpkin Group.—This group contains four varieties, Pumpkin Yam, (Early Yellow, Spanish Yam), Norton, Dooley and White Gilke. Only two of these, Pumpkin Yam and Dooley, are of much importance and these only for home use in the South and on southern markets.

Jersey Group.—The Jersey group is separated into the following sections:

1 { Roots red—Red Jersey
  Roots russet-yellow—2
2 { Stems very short and bushy—Bush
  Stems long—3
3 { Stems medium to large—Big Stem Jersey
  Stems slender—Yellow Jersey

The Red Jersey section contains the Red Jersey (Connelly's Early Red, Early Red Carolina, Red Nansemond, Van Nest Red) and Japan brown, the latter being of no commercial importance.

The stems of the bush section are very short (1 to 2½ feet) rather thick and coarse, with very short internodes and crowded leaves. The varieties in this section are Vineland Bush, Georgia Buck and Vineless Bunch Nansemond.

The Big Stem Jersey section contains the Phillipili and Big Stem Jersey, sometimes called Florida and Improved Big Stem.

The Yellow Jersey section contains two varieties, Yellow Jersey and Gold Skin. The Yellow Jersey is known under the following names, Nansemond, Early Nansemond, Yellow Nansemond, Early Carolina, Big Leaf Early Yellow Jersey, McCoy's Sweets, Red Nose, Up Rivers and Cedarville.

The Big Stem Jersey and the Yellow Jersey are by far the most important varieties grown for northern markets. All of the varieties in the Jersey group are dry and mealy.

Diseases.—Sweet potatoes are subject to diseases in the field and rots in storage. Field diseases may be divided into root and stem diseases and leaf diseases. Stem-rot, black-rot, foot-rot, scurf and root-rot affect the stems and roots, while leaf-blight, leaf-spot and white rust affect the foliage. The leaf diseases have never been serious enough to require remedial measures.

Storage rots include soft-rot, ring-rot, black-rot, dry-rot, Java black-rot and charcoal-rot. Losses from these diseases are often heavy in storage but may be reduced by proper storage methods.

The description and control measures for the various diseases of sweet potatoes are adapted from Farmers *Bull.* 1059 by Harter (64).

Stem-rot (*Fusarium batatatis* or F. *hyperoxysporum*).—The leaves of plants affected with stem-rot become dull in color and then yellowed between the veins and somewhat puckered. These symptoms are followed

by wilting of the vines. The stems are blackened inside and the discoloration may extend 3 to 5 feet from the hill. The organism causing stem-rot may also invade the roots, forming a blackened ring about a quarter of an inch below the surface of the potato. Slips from diseased potatoes are likely to be diseased.

The fungus lives over in sweet potatoes in storage and grows from diseased seed into the plants developed from them. It is important, therefore, to use only healthy seed and this can be secured by selection at digging time while the potatoes are still attached to the vines. Each hill selected should be tested by splitting the stem and potatoes should be taken for seed only from plants whose stems are not streaked with black. The seed stock should be stored in a part of the storage house where it will not come in contact with the general stock. Disinfection of the seed with corrosive sublimate, the use of fresh disease-free soil in the plant bed, crop rotation and the growing of seed from vine cuttings also aid in controlling stem-rot. When cuttings are used for growing seed the vines used should be free from disease and planted on ground that has not produced sweet potatoes for at least 6 years.

BLACK-ROT (*Sphaeronema fimbriatum*).—Black-rot may attack any under-ground portion of the plant. On the tuber the fungus produces dark to nearly black somewhat sunken, more or less circular spots on the surface. These spots enlarge and frequently nearly the whole potato is involved. On the stem the infection begins as small black spots which gradually enlarge until the whole stem is rotted off. Plants grown from tubers affected with black-rot are likely to have the disease. Black-rot causes serious storage losses.

The control measures mentioned for stem-rot should be applied to black-rot. If black-rot alone is present the seed may be selected in the spring.

FOOT-ROT (*Plenodomus destruens*).—This disease appears first as small brown to black spots on the stem of the plant near the ground. Its growth is very slow at first but eventually it girdles the plant. Soon after this the plant wilts and round, black specks, just visible to the naked eye, appear in the diseased areas. These are the fruiting bodies. The organism may grow from an infected stem on to the roots and cause a brown, rather firm rot of the potato. Later fruiting bodies standing close together develop on the surface in the form of pimple-like protuberances. This disease is not so widely distributed as stem-rot and black-rot.

Seed selection, use of clean plant beds and crop rotation are the control measures recommended. The disease is carried from the field to the storage house on the potatoes and back to the field on the slips.

SCURF (SOIL STAIN OF JERSEY MARK) (*Monilochaetes infuscans*).—Scurf appears as a brown discoloration on the surface of underground

parts of the plant. The fungus does not break the skin and may be easily scraped off by the finger nail. It is worse on heavy soils and on soils containing a large quantity of organic matter. It is also worse during a wet season and on low ground. Loss by this disease is not heavy compared to some of the others.

Treating the seed with corrosive sublimate solution and use of fresh soil for the seed bed are control measures suggested.

Root-rot (*Ozonium omnivorum*).—The root-rot is best known as the Texas root-rot of cotton and alfalfa. The organism gains access to the plant on the underground parts and spreads in both directions. It may enter the potato or cause spots on the surface. In either case a brown rot is produced resulting in the complete destruction of the potato. The organism lives over winter in the soil on dead vegetable matter, or in the far South, probably on winter crops. It is killed by hard freezing and is therefore restricted to the southern states.

This disease is difficult to control because it grows on a great variety of plants. Deep, clean cultivation, crop rotation and selection of disease-free seed are recommended.

Leaf-blight (*Phyllosticta batatas*).—Leaf-blight appears on the upper side of the leaf as roundish or angular spots one-eighth to one-half inch in diameter and separated from the healthy tissue by a dark line. Inside this line is a strip of brownish tissue which has lost most of its green color. Inside this ring is a circular area, much lighter in color, in which a number of black bodies containing spores are found. So far as is known this fungus does not attack other plants; neither does it occur on other parts of the plant than the leaf.

Leaf-blight occurs practically every year in the southern states but is less common in New Jersey, Delaware, Maryland, Kansas, Iowa and Illinois. It is seldom serious enough to require remedial measures.

Leaf-spot (*Septoria bataticola*).—The leaf-spot fungus produces spots on the leaves similar to leaf-blight. The spots, scattered indiscriminately over the foliage, are white, surrounded with a brown border. Within these white areas one or more black specks may be found. These specks contain spores which are carried by insects and other agencies to other leaves. The disease probably lives over winter on the dead leaves in the field.

It is not serious enough anywhere to require remedial measures.

White-rust (*Albugo ipomoeae-panduranae*).—The first symptom of this disease is a loss of the green color in spots on the underside of the leaf. Later these spots become brown and covered with whitish, viscid growth which is finally more or less powdery. This disease causes no great amount of harm, although it is widely distributed and occurs on a number of other plants, including wild morning glories.

Soft-rot (*Rhizopus nigricans*).—Soft-rot is one of the most destructive diseases in the sweet-potato storage house. The decay begins at one end of the potato and grows rapidly, requiring but a few days with high temperatures and a high relative humidity to destroy the entire potato. The potatoes are first rendered soft, watery and stringy, but later they become firm, hard and brittle. One soft-rot potato may communicate the disease to all of the potatoes in contact with it. The spores of the black mold produced on the surface may be carried by flies to other potatoes or may be communicated to them by handling.

Ring-rot.—This disease is caused by the same mold (common bread mold) as the soft-rot. Ring-rot differs from soft-rot in that the decay begins at a point between the two ends instead of at the ends. From the point of infection the decay forms a ring around the potato.

Dry-rot (*Diaporthe batatatis*).—Dry-rot is a disease of sweet potatoes in storage. It generally begins at the end of the potato, producing a firm brown rot. It grows slowly, the potato finally becoming dry, hard and mummified. Small domelike protuberances just visible to the naked eye finally cover the entire surface. If the skin is scraped slightly, the tissue beneath presents a coal-black appearance.

Dry-rot is widely distributed, but is not one of the more serious storage troubles.

Java Black-rot (*Diplodia tubericola*).—This disease is strictly a storage trouble. It is similar in appearance to dry-rot and is widely distributed, but is more prevalent in the South. The disease begins at the end and grows very slowly, requiring under normal storage conditions from 4 to 8 weeks to destroy the potato.

Charcoal-rot (*Sclerotium bataticola*).—This storage rot is of less economic importance than most of the others. It differs from the others of a similar appearance by the production by the fungus of minute spherical resting bodies throughout the potato, rarely on the surface. These bodies are coal black.

Control of Storage Rots.—Elimination of the field diseases which are also troublesome is one of the important control measures. Careful handling to prevent any breaking of the skin or bruising of the surface should be practiced since many of the diseases gain entrance through the injured tissues. Thorough curing and maintaining good storage conditions will materially aid in controlling storage rots. (See "Storage.")

Sweet Potato Weevil.—The sweet potato weevil (*Cylas formicarius* Fab.) is a slender snout-beetle about one-fourth of an inch long. It is very destructive to the sweet potato crop in portions of Texas, Louisiana, Mississippi, Alabama and Florida. Chittenden (24) gives an estimate of the loss by this insect in Texas, Louisiana and Florida in 1917, amounting to $2,800,000.

This insect feeds upon sweet potatoes and closely related plants, especially a species of wild morning glory found growing in sandy places along the seashore of Florida and other tropical and sub-tropical regions. The beetles feed on the leaves, vines and roots of the sweet potato. Chittenden states that the first-appearing weevils feed upon the leaves, stems and vines, then enough eggs are deposited at the base of the vine to girdle it more or less completely.

The young larvae eat into the flesh of the potato, leaving an irregular burrow lined with excrement. They feed in the root until their full growth is reached and pass the pupa stage within the potato.

Chittenden suggests the following control measures:

1. Do everything possible to prevent the transportation of weevil-infested plants to uninfested districts. Do not use seed sweet potatoes, slips or draws from weevil-infested localities . . .

2. Never use the same land for growing sweet potatoes year after year when weevils are present. Rotate with cotton, corn, tobacco, Irish potatoes, peanuts or any other profitable crop.

3. Harvest promptly and thoroughly all tubers or roots . . .

4. Disinfect all weevily roots whenever advisable (*e.g.* when soon to be eaten) with carbon disulphid or other fumigant.

5. Destroy the weevils in badly infested and inferior roots by cooking and feeding to hogs, poultry, or cattle . . .

6. After harvesting clean up the culls, vines, remnants, and rubbish remaining in the fields and burn promptly and thereafter keep the fields clean at all times.

7. Keep down volunteer sweet potatoes and all plants of the morning glory family, whether cultivated or wild.

8. Plant the new crop remote from the seed bed.

9. Spray plants with arsenicals for first-appearing weevils on leaves and stems. Dip the slips and other propagating material into arsenate of lead before planting. Kill the beetles before egg laying begins and whenever they appear in numbers.

10. Observe care in storage, keeping the tubers dry at all times to prevent secondary injury from rots . . .

Harvesting.—When sweet potatoes are grown for the early market they may be harvested as soon as the tubers reach marketable size, regardless of the stage of maturity. The main crop, which is intended for storage should be well matured before digging. When the potatoes are mature a broken or cut surface dries on exposure to the air, while an immature one remains moist and turns dark in color. However, in regions where early frosts occur the potatoes should be dug about the time the first hard frost occurs, regardless of their stage of maturity. If frost kills the vines the potatoes should be dug immediately as decay sets in on the dead vines and may pass down to the roots. In case it is impossible to dig immediately the vines should be cut away and loose soil thrown over the rows for protection from cold.

The implement used to dig sweet potatoes should be one that does not cut or bruise the roots. One of the best types of diggers is a plow with rolling colters on the beam to cut the vines and with rods attached to the small moldboard to free the roots from the soil. A large turnplow or a "middle buster" may be used. The machine digger used for Irish potatoes should not be used in digging sweet potatoes as the roots would be bruised in being carried over the rods. After the potatoes are plowed out they are scratched out by hand and left on the surface of the soil long enough to dry. The digging should be done, if possible, when the weather is bright and the soil dry.

Sweet potatoes should be graded somewhat as they are gathered so as to eliminate extra handling. Where they are marketed as soon as harvested it is a common practice to grade and pack in the field. If the potatoes are to be stored it is a good plan to go over the rows and pick up the sound marketable potatoes in one basket, then gather the seed stock in another and put the injured ones in still another. This eliminates extra handling and thereby reduces the loss by decay, since in any handling there is some bruising and this hastens decay. The baskets or other containers used for gathering the potatoes should be loaded on a wagon with springs and hauled direct to the storage house. The potatoes should never be dumped into the wagon bed.

Grading.—When the potatoes are to be marketed from storage they should be carefully graded, no matter how well they were graded at harvest time. The market prefers a medium-sized, uniform type of sweet potato, free from bruises and decayed spots. The U. S. Bureau of Markets recommends four grades, U. S. Grade No. 1, U. S. Grade No. 2, U. S. Jumbo Grade and U. S. Grade No. 3. These grade specifications are as follows:

U. S. Grade No. 1 shall consist of sound sweet potatoes of similar varietal characteristics which are practically free from dirt or other foreign matter, frost injury, decay, bruises, cuts, scars, cracks and damage caused by heat, disease, insects (including weevils), or mechanical or other means.

The diameter of each sweet potato shall not be less than 1¾ inches nor more than 3½ inches, and the length shall not be less than 4 inches nor more than 10 inches, but the length may be less than 4 inches if the diameter is 2¼ inches or more.

In order to allow for variations incident to commercial grading and handling, 5 per cent, by weight, of any lot may not meet the requirements as to diameter and length, and in addition, 6 per cent, by weight, may be below the remaining requirements of the grade.

Any lot in which the diameter is not less than 1½ inches and which contains a greater percentage by weight of sweet potatoes below 1¾ inches than is permitted in U. S. Grade No. 1, but which otherwise meets the requirements of such grade shall be designated as U. S. Grade No. 1 Medium.

Any lot in which the length is not less than 6 inches nor more than 12 inches and which contains a greater percentage by weight of sweet potatoes above 10 inches in length than is permitted in U. S. Grade No. 1, but which otherwise meets the requirements of such grade shall be designated as U. S. Grade No. 1 Long.

U. S. Grade No. 2 shall consist of sound sweet potatoes of similar varietal characteristics, not meeting the requirements of the foregoing grades, which are free from serious damage caused by dirt or other foreign matter, frost injury, decay, bruises, cuts, scars, cracks, heat, disease, insects or mechanical or other means, and which are not less than 1½ inches nor more than 3½ inches in diameter.

In order to allow for variations incident to commercial grading and handling, 5 per cent by weight of any lot may not meet the requirements as to diameter, and, in addition, 6 per cent by weight may be below the remaining requirements of this grade.

U. S. Jumbo Grade shall consist of sound sweet potatoes of similar varietal characteristics, which are free from serious damage caused by dirt or other foreign matter, frost injury, decay, bruises, cuts, scars, cracks, heat, disease, insects, or mechanical or other means, and which are not less than 3½ inches in diameter.

In order to allow for variations incident to commercial grading and handling, 5 per cent by weight of any lot may be less than the diameter prescribed, and, in addition, 6 per cent by weight may be below the remaining requirements of this grade.

U. S. Grade No. 3 shall consist of sweet potatoes not meeting the requirements of any of the foregoing grades.

Most growers should use only two grades, 1 and 2, leaving the others for feeding to live stock. In some cases only Grade No. 1 should be used, but in this case only the potatoes which meet the requirement of this grade should be packed.

Packing.—Sweet potatoes should be put up in neat, attractive packages, that are substantial. The standard veneer barrel with a burlap cover is often used in summer and autumn, while in winter a tight, stave barrel is employed to some extent. Barrels are not entirely satisfactory since they are too large. A smaller package, such as a bushel box or crate, bushel hamper or bushel round stave basket, is becoming popular. The ordinary hamper is too frail, for a product as heavy as sweet potatoes, but when made extra strong it makes a satisfactory and attractive package. Sweet potatoes should never be marketed in bags or in bulk as they become badly bruised when so handled.

When sweet potatoes are marketed in cold weather they should be protected, since chilling impairs the quality and hastens decay. Protection is usually given by lining the package with paper. Cars are often lined with paper and in very cold weather they are heated.

In packing only one grade should be put in a package and the potatoes should be well placed so that the package will be full when it reaches the

market. The package should be so full when it is packed that considerable pressure is necessary to get the cover on. This will hold the potatoes in place and prevent bruising by shaking around in the package.

Storage.—The improvement in the methods of storage during the past few years has done more to increase the value of the sweet potato crop than anything else. With good storage it is no longer necessary to put the potatoes on the market in the fall when the supply is greater than the demand. Nor is it necessary to lose 30 per cent of the crop by decay, since by using care in handling, and by storing in the proper type of storage house the loss by decay should be less than 5 per cent.

To keep sweet potatoes in good condition they must be (1) well matured before digging, (2) carefully handled, (3) well dried or cured after being put in the storage house, and (4) kept at a uniform and relatively high temperature and low humidity after they are cured.

The stage of maturity at which the potatoes should be dug is discussed under "Harvesting."

Careful handling is important since the sweet potato is very easily bruised and organisms causing decay often enter the injured surface. Even if decay does not set in the bruised areas become discolored and hard, thus injuring the appearance and reducing the quality. The sweet

Table XLV.—Relation of Cut or Bruising Injury to the Keeping of Sweet Potatoes

(Shrinkage and decay averages for three varieties kept at a temperature of 50 to 55 degrees F., seasons of 1917–1918 and 1918–1919)

Variety and condition	Average weight at harvest time, lb.	Shrinkage during curing, 19 days, per cent	Shrinkage at end of— 51 days, per cent	82 days, per cent	111 days, per cent	141 days, per cent	164 days, per cent	Weight at end of storage period, lb.	Loss due to decay, 164 days Lb.	Per cent
Uninjured:										
Big Stem Jersey..	142.56	6.59	8.02	9.42	10.88	12.09	13.54	123.25	1.81	1.27
Nancy Hall......	140.00	7.14	8.46	9.69	11.03	12.12	13.10	121.56	0.84	0.60
Southern Queen..	153.09	7.83	9.12	10.49	12.00	13.21	14.69	130.59	0.59	0.38
Total..........	435.66	.....	.....	.....	.....	.....	.....	375.41	3.25	
Average.......	......	7.23	8.55	9.88	11.33	12.49	13.83	......	.....	0.75
Injured, cut and... bruised:										
Big Stem Jersey..	73.25	14.44	19.75	23.59	27.09	30.33	33.83	48.47	20.16	27.52
Nancy Hall......	46.06	18.52	21.51	23.88	26.19	27.99	29.51	32.47	4.28	9.29
Southern Queen..	71.97	12.55	14.67	16.54	18.64	20.06	21.88	56.53	1.94	2.69
Total..........	191.28	.....	.....	.....	.....	.....	.....	137.47	26.38	
Average.......	......	14.83	18.26	21.01	23.69	25.91	28.13	......	.....	13.79

potato will not withstand as much rough handling as the Irish potato. In fact very few products are more easily injured than the sweet potato and it should be given as careful handling as apples and oranges. The importance of careful handling is shown by results of experiments reported by Thompson and Beattie (162).

Table XLV shows the shrinkage at various intervals during storage and the loss due to decay at the end of the storage period. These results were secured in an up-to-date storage house on the Arlington Experimental Farm, Arlington, Virginia.

Every potato in the injured lot was either cut, or bruised. Table XLV shows that the shrinkage at each period was practically twice as much in the injured as in the uninjured lots and the difference would have been still greater in a storage house where the conditions were less favorable than in this one. The decay was nearly 14 per cent for the injured potatoes and less than 1 per cent for those not injured. Under poor storage conditions all of the injured potatoes would probably have rotted. The shrinkage and the loss by decay was greatest in the Big Stem Jersey and least in the Southern Queen. The loss in the injured lots is greater than the figures for shrinkage and decay would indicate since they are very unattractive in appearance and require a great deal of trimming in preparing for the table.

Curing.—Sweet potatoes are "cured" by maintaining a high temperature, 80 to 95 degrees F., with good ventilation, for a period of 10 days to 3 weeks. The length of time depending upon the weather conditions and, to some extent, on the variety. During cloudy or rainy weather, when the humidity is high, a longer period is required than when the humidity is low. Ventilation is necessary to drive off the moisture-laden air. The curing is necessary to reduce the moisture content of the sweet potatoes and thus prevent the development of decay. During the curing process the potatoes should lose 6 to 8 per cent of their original weight. The doors and windows of the storage house may be closed at night and during cloudy and rainy days, but some of the ventilators should be left open throughout the curing period. The air inside the house should be kept at a higher temperature than the outside air. This will prevent moisture from being deposited on the walls and other interior portions of the house. When the potatoes are thoroughly cured the temperature should be reduced gradually to about 55 degrees F. and kept near that point during the remainder of the storage period.

Storage Temperature.—Most authorities recommend a temperature of 50 to 55 degrees F. after the curing period and this has proven very satisfactory in practice. Experiments by the U. S. Department of Agriculture (162) show that the shrinkage increased as the temperature was raised. Table XLVI gives the loss in weight at various intervals during storage and loss due to decay for the period of 164 days.

TABLE XLVI.—RELATION OF TEMPERATURE DURING STORAGE TO THE KEEPING QUALITY OF SWEET POTATOES

(Shrinkage and decay averages of three standard varieties in storage-house tests during two seasons)

Variety	Temperature, deg. F.	Weight* at harvest time, lb.	Loss in weight during curing, per cent	Loss in weight at end of—						Loss due to decay 164 days	
				51 days, per cent	82 days, per cent	111 days, per cent	141 days, per cent	164 days			
								Lb.	Per cent	Lb.	Per cent
Big Stem Jersey.......	50 to 55	142.56	6.59	8.02	9.42	10.88	12.09	19.31	13.54	1.81	1.27
Nancy Hall...........	50 to 55	140.00	7.14	8.46	9.69	11.03	12.12	18.44	13.10	0.84	0.60
Southern Queen.......	50 to 55	153.09	7.83	9.12	10.49	12.00	13.21	22.50	14.69	0.59	0.38
Total for three varieties.............	....	435.67	....	....	.....	.....	.....	60.25	.....	3.25	
Average for three varieties..........	....	......	7.23	8.55	9.88	11.33	12.49	.....	13.83	.....	0.75
Big Stem Jersey.......	55 to 60	144.16	7.74	9.02	10.82	12.59	14.24	22.50	15.61	1.69	1.17
Nancy Hall...........	55 to 60	144.47	8.50	9.73	11.12	12.74	14.30	22.31	15.45	0.72	0.49
Southern Queen.......	55 to 60	151.72	8.71	9.68	11.53	12.09	14.03	22.44	14.79	0.56	0.37
Total for three varieties.............	....	440.34	....	.....	.....	.....	.....	67.25	.....	2.97	
Average for three varieties..........	....	......	8.32	9.48	11.16	12.47	14.18	.....	15.27	....	0.67
Big Stem Jersey.......	60 to 65	139.94	7.98	9.60	12.10	13.75	15.46	23.62	16.85	3.31	2.36
Nancy Hall...........	60 to 65	143.16	9.17	11.05	13.18	14.69	15.89	24.12	16.85	0.78	0.54
Southern Queen.......	60 to 65	150.53	6.73	8.24	10.40	11.73	12.81	20.34	13.51		
Total for three varieties.............	....	433.62	....	.....	.....	.....	.....	68.09	.....	4.09	
Average for three varieties..........	....	......	7.93	9.61	11.87	13.22	14.68	.....	15.70	....	0.96

* Weight means the average weight of potatoes stored per year (total weight divided by 2).

Examination of the above table will show that the average percentage of shrinkage for the three varieties increased with a rise in temperature. This was true for every period after curing. It will also be noticed that over half of the shrinkage occurred during the curing period. After the curing period the shrinkage continues, but the rate is rather slow, averaging less than 1½ per cent a month under the three sets of temperatures. The average total shrinkage, even at the highest temperature was not excessive for such a long period and with potatoes stored in crates. The average storage period is not over 3 or 3½ months. At the end of 111 days the average shrinkage in these experiments was 11.33, 12.47 and 13.22 per cent. A shrinkage of at least 10 per cent for a storage period of 5 months is necessary and half of this should occur during the curing period. The difference in percentage of decay is not significant as the potatoes in the three storage rooms kept in almost perfect condition.

When the temperature in the storage house goes below 48 degrees F. a fire should be started, or the house opened during the middle of the day

when the temperature on the outside is higher than on the inside and the humidity of the outside air is not too high. When the temperature goes above 60 degrees F., it is desirable to open the house in the cool of the day if the weather conditions are favorable.

Comparison of Bins and Crates.—It is often asserted that crates, baskets and other small containers are better than bins, because when decay sets in it is likely to be confined to the container, but in bins the decay may spread throughout the bulk of the potatoes. The extra handling required when bin storage is used increases the chances for bruising the potatoes. In ordinary handling there is considerable bruising in dumping the potatoes into the bins.

Experiments conducted for 2 years by the U. S. Department of Agriculture (162) show that shrinkage was a little greater in crates than in bins, but decay was slightly greater in the latter. The average shrinkage for three standard varieties was 12.88 per cent in bins and 14.02 per cent in crates, while the decay was 1 and 0.57 per cent respectively. The conditions were so near ideal that the loss was practically nothing. Under less favorable conditions the difference in percentage of decay would probably have been greater.

Sorting Versus Not Sorting.—It has been quite generally believed that when sweet potatoes begin to decay in storage they should be sorted to pick out the diseased ones. Experiments reported by Thompson and Beattie (162) indicate that it is inadvisable to disturb the potatoes even to pick out those that are decaying. In seven tests, including three varieties, covering 4 years the average loss by decay was 2.63 per cent for those sorted and 1.21 per cent for those not sorted. In six lots out of the seven the sorted potatoes had the larger percentage of decay. The sorting was carefully done about once a month during the storage period which averaged 134 days. Under less careful handling there would undoubtedly have been more decay in both sorted and unsorted lots, but especially in the former. The probable explanation of the greater amount of decay in the sorted lots is that slight bruising resulted from handling and that the sorting increases the chance of spreading disease from decayed to sound potatoes. One decayed potato left undisturbed might be in contact with several sound ones, all of which would eventually become diseased, but it would require considerable time for all of them to decay completely. When sorted each of the potatoes, which had become infected with disease, might be placed in contact with several uninfected ones, thereby spreading the disease to them.

Since sorting apparently increases disease injury and requires considerable labor, it seems inadvisable to sort them until they are to be placed on the market. When decay is serious the potatoes should be sorted and disposed of immediately.

Changes during Storage.—Attention has been called to the loss in weight of sweet potatoes in storage. Tables XLV and XLVI show the percentage loss in weight at various times during storage. It has been assumed that the decrease in weight is accounted for by the loss of moisture, but this does not account for all of it. The percentage of water in sweet potatoes does not vary to any great extent during storage, although it is well known that moisture is lost.

Other changes which take place in the sweet potato during storage are transformations of carbohydrates, notably a decrease in starch and an increase of sugar. Harrington (60) found that there was an increase in the total amount of sugar up to March 6, beyond which his experiments were not continued. Shiver (135) found that during the time of his experiments (up to April 17) there was a gradual decrease of starch

Table XLVII.—Carbohydrate Transformations in Sweet Potatoes during Storage

(Adapted from Hasselbring and Hawkins)

Big Stem Jerseys

Date	Water, per cent	Starch, per cent	Cane sugar, per cent	Reducing sugar as glucose, per cent	Total sugar as glucose, per cent	Total carbohydrates as glucose, per cent
Oct. 20	73.50	19.07	1.90	0.90	2.90	24.09
Nov. 8	72.99	16.94	3.51	1.32	5.02	23.85
Dec. 6	71.89	16.42	3.94	1.40	5.55	23.79
Jan. 4	72.06	16.02	4.39	1.28	5.90	23.70
Feb. 1	72.18	14.11	6.06	1.67	8.04	23.71
Mar. 1	71.97	13.09	6.96	1.44	8.76	23.31
Mar. 20	73.02	13.44	6.40	1.10	7.84	22.77
Mar. 26	72.49	14.47	5.61	0.87	6.77	22.85
Apr. 16	72.87	14.20	6.03	0.90	7.24	23.02
June 1	72.45	14.62	5.85	0.87	7.02	23.27

Southern Queen

Date	Water, per cent	Starch, per cent	Cane sugar, per cent	Reducing sugar as glucose, per cent	Total sugar as glucose, per cent	Total carbohydrates as glucose, per cent
Oct. 23	71.69	22.09	1.19	0.39	1.64	26.18
Nov. 10	68.41	19.87	2.97	0.77	3.89	25.96
Dec. 7	67.69	19.30	3.50	0.72	4.41	25.85
Jan. 11	67.51	19.75	3.53	0.75	4.46	26.41
Feb. 3	68.02	19.22	3.95	0.60	4.75	26.11
Feb. 28	68.00	18.99	4.05	0.53	4.80	25.90
Apr. 8	66.71	20.35	2.93	0.52	3.61	26.22
May 4	69.21	19.78	3.39	0.51	4.07	26.05
June 4	68.15	20.15	2.80	0.55	3.50	25.89

and an increase of cane sugar, while the invert sugar showed but slight fluctuations. Hasselbring and Hawkins (71) show the changes in two varieties, Big Stem Jersey and Southern Queen, from harvest October 20, 1911 to June 1, 1912. These potatoes were held at temperatures ranging from 11.7 to 21 degrees C. after the curing period, but mainly between 11.7 to 16.7 degrees C. Table XLVII shows the percentage of water, starch, cane sugar, reducing sugar as glucose, total sugar as glucose and total carbohydrates as glucose. The percentages of carbohydrates were all referred to the original moisture content of the potatoes.

Hasselbring and Hawkins (71) comment as follows on the results of these experiments:

> The data . . . show that under the condition of this experiment the moisture content of the roots remain fairly constant. There is a slight decrease in the moisture content, more marked in the Southern Queen than in the Big Stem variety, during the curing process, but on the whole there is comparatively little change in the percentage of moisture. The loss of moisture is probably compensated in part by the water formed in respiration while the loss in substance by respiration would increase the relative moisture content, thus tending to conceal the actual water loss.

Similar experiments with sweet potatoes stored at low temperatures (approximately 4 degrees C.) show that the disappearance of starch and the accumulation of sugar take place more rapidly and proceed to a greater extent than at high temperatures. The cold storage experiments were of short duration since the potatoes rotted after having been kept at low temperatures for about 6 weeks.

Hasselbring and Hawkins (71) give the following brief summary of results of their studies of the physiological changes in sweet potatoes during storage:

> During its growth the sweet-potato root is characterized by a very low sugar content. The reserve materials from the vines are almost wholly deposited as starch.
>
> Immediately after the roots are harvested there occurs a rapid transformation of starch into cane sugar and reducing sugars. This initial transformation seems to be due to internal causes and is largely independent of external conditions. Even at a temperature of 30 degrees C. both cane sugar and reducing sugars accumulate during this initial period in excess of the quantity used in respiration, while during subsequent periods the quantity of reducing sugar diminishes at that temperature as a result of respiration. These initial changes seem to be associated with the cessation of the flow of materials from the vines.
>
> In sweet potatoes stored at a temperature of 11.7 to 16.7 degrees C., the moisture content remains fairly constant. There is a gradual disappearance of starch during the first of the season (October to March) and probably a re-formation of starch accompanied by a disappearance of cane sugar during the latter part of the season (March to June). The changes in reducing sugar are less

marked than those in cane sugar. The changes in starch and cane sugar appear in a general way to be correlated with the seasonal changes in the temperature.

In sweet potatoes kept in cold storage (4 degrees C.), there is a rapid disappearance of the starch and an accompanying increase in cane sugar. These changes do not attain a state of equilibrium at that temperature, as the sweet potatoes invariably rot by the action of fungi before the changes have reached their maximum. At both high and low temperatures cane sugar is the chief product formed by the conversion of starch in the sweet potato. The quantity of invert sugar in the root at any time is comparatively small.

The changes in sweet potatoes during storage, especially the decrease in starch and the increase in sugar, account for the difference in taste between freshly dug potatoes and those of the same variety which have been stored for a while. Freshly dug sweet potatoes are dry when cooked, while stored potatoes are more moist. The so-called dry-fleshed varieties have a lower sugar content than the moist-fleshed varieties. Analyses by Harrington (60) March 6, 1894 of a number of varieties show a variation of total sugar from 7.55 per cent in the Delaware (probably a Jersey) to 19.71 per cent in the Early Bunch Yam a moist-fleshed variety. Nansemond (Yellow Jersey) a dry-fleshed potato contained 8 per cent total sugar. All of the so-called moist-fleshed varieties are high in sugar. The moisture content of the two types is practically the same.

Storage Houses.—The following description of the method of construction of the type of house recommended by the U. S. Department of Agriculture was prepared by the author and published in Farmers' *Bull.* 970:

Sweet-potato storage houses may be built of wood, brick, hollow tile, cement, or stone. Wooden houses are preferable, because they are cheaper and easier to keep dry than the other types. It is difficult to keep moisture from collecting on the walls of a cement, stone, or brick house. Where such houses are built for sweet-potato storage they should be lined with lumber, so as to keep the air in the house from coming in contact with masonry walls. It is best to build sweet-potato storage houses on foundations that allow a circulation of air under them. The "dugout," or house built partly under ground, is not satisfactory for storing sweet potatoes in the South, because it is practically impossible to keep this type of house dry, and moisture in the storage house will cause the crop to rot.

The foundation of the storage house may be in the form of pillars or solid walls and should be of such a height that the floor is about on the level of the bottom of the wagon bed, while the footings should be carried below the frost line or to solid ground. Girders 6 by 10 or 8 by 8 inches in size are usually placed on the pillars.

Where cement, brick, or stone foundation walls are built, they should extend 18 to 20 inches above the ground level; and plates 2 to 3 inches thick and 8 to 10 inches wide should be placed on the wall. In using walls for the foundation it is necessary to provide means for ventilation under the house. This can be

done by placing small windows in the foundation every 10 to 12 feet. Even where solid outside foundation walls are used it is advisable to use pillars for the center supports. The rows of pillars should be not farther apart than 8 to 10 feet.

The walls, floor, ceiling and roof should be well-insulated so that changes in temperature of the outside air will not be readily felt on the inside of the house. In most storage sections the walls should have at least two layers of boards on the outside of the studs and two on the

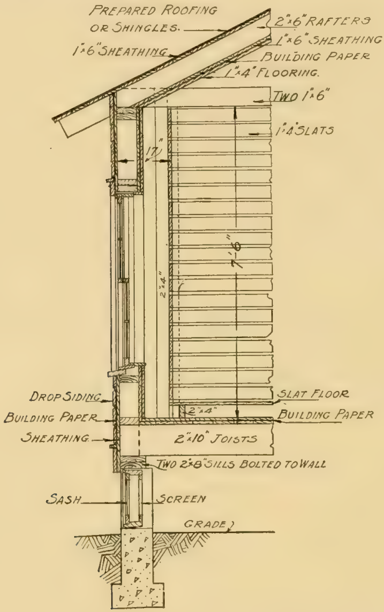

Fig. 27.—Details of construction of a sweet-potato storage house. (*Courtesy, U. S. Department of Agriculture*).

inside with building paper between the layers. The space between the walls should be left open, because sawdust, shavings and other materials used to keep out cold or heat, will absorb moisture, and when once wet will never dry out. The floors and ceiling should have at least two layers of boards with building paper between, and in the colder regions more insulation is desirable. Figure 27 shows the details of construction recommended by the U. S. Department of Agriculture (160) for sweet-potato storage houses in the South.

Thorough ventilation is necessary in a storage house. This is provided by means of doors, windows, and ventilators through the floor

and through the roof as shown in Figs. 28 and 29. The openings in the floor around the stove prevent overheating the potatoes near the

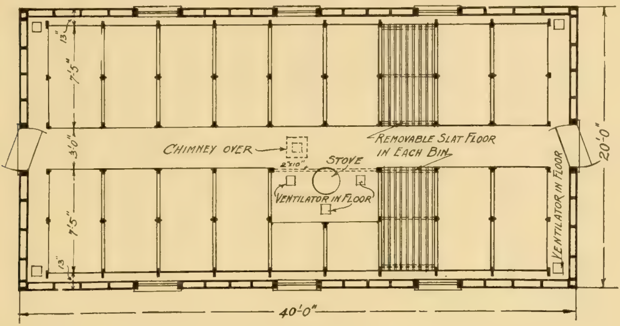

FIG. 28.—Floor plan of a 20 by 40 foot sweet-potato storage house. (*Courtesy, U. S. Department of Agriculture*).

stove. The windows and doors must be made so as to close tightly and the ventilators should be made so they can be closed quickly and tightly whenever necessary. Openings in the floor as shown in Fig. 28 are satis-

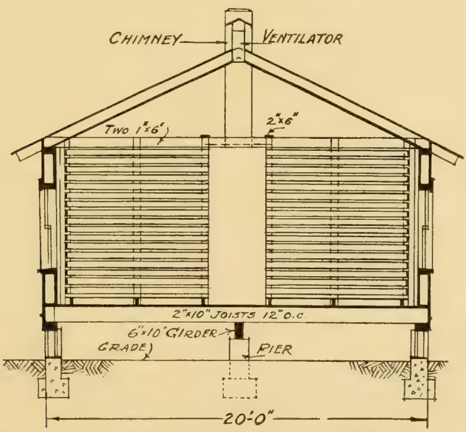

FIG. 29.—Cross section of a 20 by 40 foot sweet-potato storage house. Note space under bin and between bin and walls of house. (*Courtesy, U. S. Department of Agriculture*).

factory for bottom ventilation and box ventilators through the roof as illustrated in Fig. 29 serve to carry off the warm, moisture-laden air as it rises.

The arrangement of the interior of the house depends upon the methods of storage used. If the potatoes are kept in boxes, baskets, hampers or crates no interior construction is necessary, but it is desirable to set the packages on false, slat floors, raised 2 to 4 inches above the floor of the house. When bins are employed the interior of the storage should be arranged for convenience in handling the potatoes, and in taking care of heating and ventilation. The bins are often made as follows:

For the corner and middle supports, 2- by 4-inch scantlings are set up, the lower end nailed to the floor and the upper to the crosspieces used for tying the sides together. Over the supports, 1- by 4-inch boards are nailed, leaving a 1-inch space between them. In making the slat floors, 2- by 4-inch scantlings are cut to go across the bin and placed on edge, one near each end and one in the center. To these 1- by 4- or 1- by 6-inch boards are tacked, leaving a 1-inch space between them. If left loose, the slat floor racks can be taken out when the house is cleaned and disinfected during the summer. The size of the bins will depend somewhat on the arrangement and size of the house, but it is not advisable to make them more than 5 feet wide, 6 to 8 feet deep, and 10 to 12 feet long. There should be a 6- to 12-inch space between the walls and the bins to allow a circulation of air. It is necessary to slat up both sides of the scantlings between the bins, in order to leave an air space between the potatoes in the different bins. The construction here described allows a 4-inch space between the bins, a 4-inch space under the bins and 6 inches between the bins and outside walls. (See Figs. 27 and 29.)

Heating the Storage House.—The type of heating apparatus used depends to a considerable extent upon the size of the house. For a small house a small sheet-iron, wood-burning stove or a small coal stove may be used. Oil stoves are used for small houses in some sections of the South, but these are not entirely satisfactory. For large houses, hot-water or steam heat is preferable to the use of stoves since the heat can be more evenly distributed than with stoves, or even with hot-air furnaces. Some houses are heated by hot-air furnaces with the air pipes placed under the bins. No experimental comparison of the different methods of heating has been made. In a small house where only one stove is used it is usually placed near the center but if cold winds strike one end the stove should be in that end. Some storage houses have a small stove in each end, and this is a good arrangement. In large houses it is desirable to put in partitions to make separate rooms. Each room should have a stove or other independent heating unit so that any part of the house can be heated without heating the other parts.

Storage Pits.—A large part of the sweet potato crop, grown in the South, is stored in out-door pits or banks although the percentage so stored is decreasing each year. The average loss by decay by this method of storage is at least 30 per cent, but this can be materially reduced by using care in handling the potatoes and in constructing the pit or

bank. Experiments to compare house and pit storage, were conducted by the U. S. Department of Agriculture (162) for 3 years in the South. Records covering ten tests secured on 984,000 bushels of sweet potatoes stored in houses showed only 1.20 per cent loss due to decay, while the decay averaged 14.33 per cent in the same number of tests on 204,300 bushels stored in pits. In these experiments the potatces were handled carefully and the pits were much better than the average. In addition to the loss by decay in pits and banks the quality of the potatoes is very inferior, due to lack of proper curing, and they decay rapidly when removed. It is very inconvenient to get the potatoes out of a pit or bank when needed, especially during cold, or rainy weather.

CHAPTER XXIV

BEANS AND PEAS

Broad Bean	Tepary Bean
Kidney Bean	Soybean
Scarlet Runner or Multiflora Bean	Cowpea
Lima Bean	Peas

Beans and peas are closely related botanically, but their cultural requirements have few points in common. The beans, grown in America, are tender, warm-season plants, while the pea is a hardy, cool-season plant. Both are legumes and are capable of utilizing atmospheric nitrogen by the aid of bacteria found in the nodules on the roots of the plants. They are considered good crops to grow in the rotation.

BEANS

The term "bean" as used in the United States includes the following species representing six genera: (1) Broad beans or Windsor bean (*Vicia faba*), (2) common garden bean or kidney bean (*Phaseolus vulgaris*), (3) scarlet runner or multiflora bean (*P. multiflorus*) also called P. *coccineus*, (4) sieva and lima bean (*P. lunatus*), (5) tepary (P. *acutifolius* var. *latifolius*), (6) soybean (*Glycine hispida* or *Soja Max*, (7) cowpea or China bean (*Vigna sinensis*), (8) velvet bean (*Stizolobium spp.*), (9) hyacinth bean (*Dolichos lablab*) and (10) several species of oriental beans, including adsuki, urd, mung, moth and rice beans belonging to the genus Phaseolus.

Soybeans, cowpeas and velvet beans are grown mainly as forage and as soil-improving crops, although the first two are used as human food. Hyacinth bean is grown mainly as an ornamental climber in the United States. The species of oriental beans are little known in this country, but they are likely to attract attention.

Irish (75) gives the following key to the principal species of Phaseolus:

Seed less than $\frac{3}{4}$ inch long, or if longer much flattened and usually subreniform.

Seed with conspicuous rays from the hilum to the dorsal suture, lunate or subreniform, much flattened except in one variety.

Flowers small, greenish white *P. lunatus*.

Seed with inconspicuous or no rays, rarely lunate. Flowers of medium size, white or purplish-violet. *P. vulgaris.*

Seed more than ¾ inch long, more or less tumid, less than twice as long as broad, not usually reniform. *P. multiflorus.*

BROAD BEAN

The broad bean is a hardy plant, native of Europe and Asia. It is one of the most ancient of the cultivated esculents, having been grown by the ancient Greeks and Romans, Hebrews and Egyptians. It is said to have been introduced into China about 2,822 B. C. This bean is seldom grown in America since the summers are too hot and the winters of the North are so cold that it cannot be planted in the autumn and carried over. In some sections of the South and of the Pacific coast the seed may be planted in the autumn or during the winter for a spring crop, but other types of beans are so easily grown that the extra effort necessary to produce the broad bean does not seem to be justified. In southern Europe the seed is often planted in the fall and the young plants are protected during the winter. Broad beans are used either as green or dry beans, and as feed for horses.

The broad bean is grown to some extent in California, where it is planted in February and March in the warmer sections and later in the cooler regions, near San Francisco. Hendry (72) states that 30 to 40 per cent is used as stock feed within the State, the remainder being shipped to New York and other eastern cities where it is used principally by the poorer class of Italian and Jewish peoples.

> It has fallen into comparative disrepute in California of late because of the stringency of the Federal Foods and Drugs Act, which classes weevil-infested Horse Beans as adulterated food, and prohibits their shipment in interstate commerce for use as human food. The numerous confiscations in transit under this regulation have occasioned losses to shippers, kept the price down, and retarded the expansion of the acreage.

COMMON OR KIDNEY BEAN

The kidney bean (*P. vulgaris*) is the most important species of bean grown in the United States and in common usage the term "bean" applies to types and varieties belonging to this species. This crop is grown by a large percentage of home gardeners, and, as a market crop, it is produced for market as snap beans, green shell beans, and dry beans.

Statistics of Production.—The census report gives the acreage of green beans grown for sale in 1919 as 71,970 acres and the value $8,031-449. The principal producing states were Florida with 8,522 acres,

New York 6,628, New Jersey 6,091, Maryland 5,187, Tennessee 4,322, California 4,126, Kentucky 3,358, Virginia 3,024, Wisconsin 2,548, Pennsylvania 2,497, West Virginia 2,364, Michigan 2,073 and Ohio 2,068 acres. Seven other states produced between 1,000 and 2,000 acres each. In several of the northern states a large part of the acreage of beans is grown for canning, while in the southern states the crop is grown largely for shipping to northern markets during the winter and spring.

The dry bean industry is much more important than the green bean industry. The acreage, production and value of dry beans, including varieties of Lima, Tepary and Pinto beans, produced in the six most important states for the years 1918, 1919 and 1920 as given in the *Monthly Crop Reporter* (Dec., 1920) were as follows:

Year	Acres	Production bu.	Value
1918	1,174,000	17,397,000	$91,863,000
1919	1,002,000	11,935,000	51,051,000
1920	849,000	9,075,000	27,114,000

During the War and immediately after the crop of beans was abnormally large and the price was abnormally high.

The most important dry bean states are California, Michigan, New York, Colorado, New Mexico, and Arizona, the last two growing mainly the types known as Tepary beans and Pinto beans.

History and Taxonomy.—The common bean is probably a native of South America and is undoubtedly of ancient origin. Many varieties were grown by the American Indians before they became generally cultivated in Europe.

It belongs to the family Legumnosae and is therefore closely related to the pea, clovers, and many other plants of great economic importance. Irish (75) gives the following description of the plant.

> Plant sub-glabrous, dwarf or climbing 6 feet or more. Leaflets ovate-acuminate often oblique. Flowers in racemes shorter than the leaves, white or purplish-violet, mediumsize. Pods flattened to sub-cylindrical, straight or curved, more or less turgid. Seed variable in size, shape and color.

Soil Preferences.—Beans are grown on practically all types of soils from light sandy loams to heavy clays. In California peat soils are used for growing dry beans with very satisfactory results. For an early crop

of snap beans a sandy loam is preferred, but heavier, more retentive soils of a loamy nature are desired for the growing of string beans during mid-season, and for dry beans. While a fairly rich soil is desirable beans will produce some crop on relatively poor soils. A very rich soil is not desirable because on such a soil too much vine growth is produced. Very heavy soils are not satisfactory since excess water does not drain away readily.

Fertilizers and Manures.—Authorities agree that the mineral elements, phosphorus and potash are of greatest importance. This is undoubtedly true with field beans and with late maturing varieties of garden beans, but for quick maturing varieties, especially when planted early in the season some readily available nitrogen is needed. On sandy loam soils of low productivity an application of 800 pounds of a 5–10–5 mixture is none too heavy for a crop of early snap beans. Heavier applications are used by many truck growers in the South and by market gardeners in the North.

Green beans for the cannery are usually grown in rotation with general farm crops on fairly rich land and are given only a light application of fertilizer. Some growers use nothing but acid phosphate at the rate of 300 to 400 pounds to the acre, while others use 300 to 600 pounds of a complete mixture. Where manure is used in the rotation phosphorus only is needed.

Dry beans are also commonly grown in rotation with general farm crops and only light applications of fertilizer are used. Acid phosphate at the rate of about 300 pounds to the acre is often used. Light applications of complete mixtures, containing 2 to 3 per cent nitrogen, 8 per cent phosphoric acid and 4 to 8 per cent potash, are often used. Applications larger than 300 pounds to the acre have seldom proved profitable.

Fertilizers are usually applied broadcast at the time of preparing the soil.

Manure may be used in light applications, but it is better to apply it to other crops. Heavy applications of manure should never be used for beans on account of the danger of making too large vine growth.

Planting.—Common beans are tender to frost and are usually planted after the danger of frost is over. Home gardeners and persons growing string or snap beans for the early market often take chances on frost and make a small planting before danger of frost is over. The main crop of green beans, especially those grown for the cannery, and all types grown for dry beans are planted after danger of frost is over and the soil has become warm. Where earliness is not an important factor it is not advisable to plant beans until the soil is warm for in a cold soil germination is likely to be poor.

Bean seed is planted by hand in most home gardens, but commercial plantings are usually made with a machine. The hand seed drill is used where relatively small areas are planted. For large plantings two-row corn planters, with special bean plates are used to a considerable extent and the ordinary wheat drill is also used. When the ordinary wheat drill is used some of the openings are plugged up. The 11-row grain drill, with a space of 7 inches between each drill tube can be adjusted for planting in rows 28 inches apart by stopping up all of the feed cups except the second, sixth and tenth.

The spacing of the rows and the seeds in the row should be determined by the type or variety, the richness of the soil and the amount of moisture. Large growing plants should be given more space than small plants and on rich soil more space is needed than on poor soil, provided the rainfall is sufficient, or irrigation is practiced. In dry-farming more space is given than under irrigation or in humid regions. Most bush beans are now planted in drills rather than in checks, although the latter method is followed to some extent, especially in sections of the Northwest. In the hill method 6 to 8 seeds are planted in each hill spaced 30 to 36 inches apart each way for dry beans. This practice is not recommended except where the land is very weedy. Experiments by Corbett (29), 1895, comparing the two methods of planting, gave results decidedly in favor of drilling the seed. The yield from seed planted 4 to 6 inches apart in drills was about double the yield from the same amount of seed planted in hills 18 inches apart. Other experiments, have shown similar results. Drilling the seed gives a much better distribution of plants and eliminates crowding. Seeds of garden beans are commonly spaced 2 to 4 inches apart in rows 2 to 3 feet apart, but 2 inches is too close for any variety. Spacing 4 to 6 inches apart would give better results with most garden varieties. Most field beans are planted 4 to 6 inches apart in rows 24 to 36 inches apart although on dry land a greater distance is given. Garcia (52) recommends 6 to 12 inches apart in the row for Pinto beans 6 inches giving the largest yield at the Experiment Station in New Mexico.

Pole beans are planted in hills, 3 by 3, 3 by 4, or 4 by 4 feet apart and 4 to 6 seeds are planted in each hill and then thinned to 3 or 4 plants if necessary. The poles are set before the seeds are planted and the hills are often raised a few inches to secure good drainage. Another method of planting this type of bean is to sow the seed in a drill the same as bunch beans and use a wire trellis for supporting the plants. Some types of pole beans (cornfield beans) are planted with corn and the corn stalks serve as supports for the vines.

The amount of seed, of course, varies greatly, depending upon the spacing and the size of seed. Durst (41) gives the following table showing the quantity required per acre with the rows 28 inches apart, and the seeds drilled 4 inches apart in the rows:

Table XLVIII.—Quantity of Seed for Various Varieties of Beans Planted 4 Inches Apart in Rows 28 Inches Apart

Variety	Number of seeds in an ounce	Pounds required to plant an acre
Navy	124	28.2
New White Seeded	96	36.4
Davis Kidney Wax	77	45.5
Michigan White Wax	78	44.8
White Marrow	68	51.5
Red Kidney	63	55.5
Dwarf Horticultural	54	64.8
Improved Goddard	44	79.5

Hendry (72) recommends planting the Tepary, Red Mexican, Pink, Lady Washington and Small White 6 to 10 inches apart in rows 26 to 30 inches apart. At 6 by 28 inches 8.8 pounds of Tepary beans seed would be required for an acre, 27.3 for Lady Washington, 32.6 for Pink and 23.8 for Red Mexican.

The depth of planting varies, but beans should be planted no deeper than is necessary to get the seed into moist soil. The depth should be less on heavy than on light soils. In humid regions 1½ to 2 inches deep on heavy soils and 2 to 3 inches on light soils are the usual depths of planting. Garcia (52) gives results of experiments in planting at different depths on wet soil (irrigated before planting) and on dry soil (irrigated after planting). The best germination on wet soil was at the depths of 3 and 4 inches. At 1 inch deep the germination was poor. On dry soil 1, 2, and 3 inches gave the highest germination, while the germination was very poor at 4 and 5 inches deep. Irrigating the soil after the seed is planted tends to pack the soil and the surface soon loses its moisture hence the germination is poor if shallow planting is practiced.

Cultivation.—Clean, shallow cultivation should be practiced. Deep cultivation is likely to cause injury by destroying the roots near the surface. When the plants reach full size cultivation should cease unless weed growth is heavy. Usually three to five cultivations are sufficient to keep down weeds and to maintain a satisfactory mulch. The mulch is not of much importance when the plants reach full size as they fairly well cover the ground and prevent rapid evaporation of moisture from the soil.

Cultivation should not be given when the vines are wet, since the spores of the anthracnose organism are easily carried from diseased to healthy plants at such times.

Supporting Pole Beans.—Poles 8 to 9 feet in length are usually employed to support climbing varieties of beans. The bark and stubs of the small branches are left on the poles as the rough surface is an advantage to the plants. The poles are set in the ground to the depth of 18 to 24 inches before the beans are planted. If kept under cover when not in use the poles will last several years.

Various forms of trellis supports are used to some extent. Heavy posts are set at the ends of the rows and lighter posts or stakes are set at intervals of 20 to 25 feet, then two strands of No. 10 wire are fastened to the posts, one at the top and one near the ground. Light twine is used to connect the two wires. The twine is fastened to the lower wire then passed over the upper wire and back under the lower one and continued in a zigzag fashion to the end of the row. The bean plants twine around the string until they reach the upper wire. This method of supporting the vines makes picking less difficult than when poles are used, but is expensive.

Varieties.—Varieties of beans are listed under hundreds of names, but many of these are synonyms. Jarvis (79) found that the Red Valentine variety was listed under 67 different names and many other well-known varieties have many synonyms. He described 150 true varieties as follows: 40 dwarf wax-podded, 75 dwarf green-podded, 10 climbing wax-podded and 25 climbing green-podded. Tracy (165) described 185 varieties.

Various methods of classification of varieties of beans have been developed. Irish (75) classified them on the basis of seed, pod and vine characters. Tracy (165) based his classification largely on vine, pod, and blossom characters, while Jarvis (79) based his classification and key entirely on the seed, but in the description of varieties the plant characters were used. All of these workers give comprehensive keys to cultivated varieties and complete detailed descriptions of those grown in the United States.

Varieties of beans may be classed according to their uses as (1) string or snap beans, those grown for the edible pod; (2) green-shell beans, those which are used in the green-shelled condition and (3) dry-shell beans or ripe seed, those used in the dry state. Beans are also classed according to the color of the pods as, green-podded and yellow- or wax-podded. For convenience in grouping beans are divided into dwarf or bush varieties and climbing varieties, and as field and garden beans. The term "field beans" is usually applied to those grown for use in the dry state and includes four types, kidney, marrow, medium and pea. Gilmore (55) suggested the following key for the identification of the four types of field beans:

Seed 1.5 cm. or more in length, more or less reniform, ratio—length, width, thickness 1–.4869–.3731—Kidney.

Seed between 1 and 1.5 cm. in length. Thickness exceeding half the length, 1–.6537–.6029—Marrow.

Seed 1 to 1.2 cm. in length. Thickness less than half the length 1–.678–.4975—Medium.

Seed .8 cm. or less in length, not reniform 1–.7467–.6096—Pea.

Some of the most important varieties of field beans of the various types are the following:

Pea beans: Boston Small Pea, Marrow Pea, Medium Pea, Snowflake, Navy, Michigan Robust. The last named is resistant to the mosaic.

Medium: White Wonder, Burlingame Medium, Blue-pod Medium.

Marrow: Yellow Eye; White Marrow. Red Marrow.

Kidney: White Kidney, Red Kidney, White Imperial and Wells Red Kidney.

The last two are especially desirable where anthracnose is serious as they are quite resistant to this disease.

Some of the important varieties of garden beans in the various classes are as follows:

Dwarf Wax-podded: Wardwell Kidney Wax, Hodson Wax, Pencil Pod Black Wax, Davis White Wax, Refugee Wax, Golden Wax.

Dwarf Green-podded; Burpee Stringless Greenpod, Refugee or 1,000 to 1, Red Valentine, Goddard or Dwarf Horticultural (Green shell beans), Bountiful and Early Refugee.

Climbing Wax-podded; Golden Cluster, Mont d' Or. and Kentucky Wonder Wax.

Climbing Green-podded; Kentucky Wonder, Creaseback and Lazy Wife.

Diseases.—Beans are subject to several very serious diseases, including anthracnose or pod spot, bacterial blight, mosaic, dry root-rot and rust.

ANTHRACNOSE (*Colletotrichum lindemuthianum*).—This disease is often known among growers as rust. It attacks the stems, leaves and pods and the seeds of the plants. On the stems and leaf-veins it causes elongated, sunken, dark-red cankers. On the pods the disease causes rounded or irregular sunken spots with pink centers surrounded by a darker reddish border. In severe cases the pod may be entirely covered by the spots and produce no seed. In other cases the fungus penetrates the pods and enters the seed, causing dark spots. Diseased seeds and refuse from diseased plants carry the fungus from season to season.

Control measures suggested by Orton (111) are as follows:

Save seed from perfectly healthy pods, selected with great care for entire absence of spotting. Carefully keep them away from diseased pods, shell by hand to avoid reinfection, and plant on clean land. Pull and burn any plants showing disease.

In the absence of such disease-free seed (1) secure for planting seed having the least possible amount of disease as shown by actual examination; (2) all seed should be hand picked and no seed showing the slightest discoloration should

be planted; (3) practice crop rotation and never plant beans on land where there is any refuse of last year's crop; (4) do not cultivate or walk through the bean field or pick beans while wet with dew or rain. If the disease is present it is easily spread from one part of the field to another.

The use of resistant varieties, such as Wells Red Kidney and White Imperial, is probably the most satisfactory method of control where anthracnose is serious.

Bacterial Blight (*Bacterium phaseoli*).—Bacterial blight or bean blight produces irregular diseased areas, which at first have a water-soaked appearance, but later become brown and brittle. On the pods the disease starts as slightly raised pustules which later enlarge and become irregular in shape and amber in color. Infected seeds show yellow blotches or are entirely yellowed and shriveled.

This disease is very difficult to control but the same methods as for anthracnose are recommended.

Mosaic.—This disease shows on the leaves as alternate light and dark green areas. No causal organism has been discovered. The disease is said to be carried over in the seed.

Seed from disease-free fields should be used for planting. Marrow and Yellow-eye beans are resistant to the disease and the Red Kidney is somewhat resistant. Michigan Robust bean, a high-yielding strain developed at the Michigan Agricultural College is highly resistant to mosaic while other pea beans and medium beans are very susceptible.

Dry Root-rot.—This disease, due to a species of Fusarium, is very serious in some bean-growing sections. The fungus affects the parts below the surface of the soil causing a dry rot.

No satisfactory control measures have been found for this disease. Breeding for the production of strains resistant to the Fusarium gives promise of results, but no commercial, resistant strain is available at present. Planting on land free from the organism, practicing long rotations and avoiding the use of bean straw or manure on uncontaminated soil are recommended.

Rust (*Uromyces appendiculatus*).—The rust is very widespread, but is not considered serious in most bean-growing states. It is, however, serious in Virginia, West Virginia, Tennessee, Georgia, Louisiana, and Southern California. The losses due to the rust are indirect, being due to decreased vigor on account of foliage injury.

This disease should not be confused with anthracnose which is sometimes called "rust." The seed catalogues use the name rust for anthracnose and their so-called "rust-proof" or "rust-resistant" varieties are supposed to be resistant to anthracnose. The rust attacks the leaves chiefly and all of the injury results from infection of the leaf. The leaves are covered with small, reddish-brown spore masses. Within a few

days after the rust pustules appear the leaf begins to turn yellow and later brown, then it dries up and drops off.

Fromme and Wingard (50) recommend the use of rust-resistant varieties as follows:

Dry shell beans: Dwarf Horticultural and Red Kidney, for colored beans; White Marrow and White Kidney for white beans. Avoid Navy, Snowflake, Pinto, Pink and Tepary.

Pole beans: Horticultural Pole, Lazy Wife for green-pods and Mont. d' Or for wax-pod. Avoid Kentucky Wonder, Creaseback, Virginia Cornfield, etc.

Green-Pod beans: Black Valentine, Burpee's Stringless, Hodson Green-pod, Low's Champion, Refugee and Warren.

Wax-Pod beans: New Pearl and Pencil Pod.

Bean Insects.—Many insects attack the bean, the most important being the bean weevil, bean leaf beetle, bean lady bird, bean thrips, bean aphis, and bean fly or seed corn maggot.

Bean Beetle (*Bruchus obtectus*).—This insect is a small dull-colored beetle found in stored beans. The eggs are laid in the pods in the field and the larvae or grubs develop in the seeds and transform into beetles in cavities just under the seed coat. The beetle cuts a circular opening through the seed coat in emerging. Several beetles may develop in a single seed. In the South there may be six or more generations in a year, but in the North there is usually only one generation a year. Where there is more than one generation the breeding may be continuous in storage. The number of generations depends upon the temperature.

Beans infested with weevils should not be planted since the germination is likely to be poor. The weevils in the beans can be killed by fumigating with carbon disulphid at the rate of 3 to 8 pounds to each 1,000 cubic feet of space to be fumigated, the amount to be used varying with the tightness of the container and the temperature. The liquid should be poured over the top of the seeds to be fumigated. It quickly vaporizes and the gas, being heavier than air, sinks to the bottom of the container, filling the air spaces. For best results the temperature should be 75 degrees F. or above. It is not effective at 60 degrees F. or below. For fumigating small quantities place the beans in a tight receptacle and use 1 ounce to each bushel to be fumigated. Heating the beans to 120 to 145 degrees F. for several hours also destroys the weevil. At low temperatures the insects do not feed and cause damage; hence storing in cold storage prevents injury.

In addition to the common bean weevil there are several other species which attack beans, but the same control measures are effective for all of them.

Bean Leaf Beetle (*Cerotoma trifurcata*).—This insect is a small beetle, about $\frac{1}{5}$ inch long, yellowish to reddish and has 6 black dots on the wing covers. The beetles eat large holes in the leaves, feeding from the

underside. The eggs are laid on the ground at the base of the plant and the grubs feed on the roots and the main stem just below the surface. From one to three broods occur each year, depending upon the length of the growing season.

Spraying with arsenate of lead, 4 pounds of paste or 2 pounds of powder to 50 gallons of water, will kill the beetle if both sides of the leaves are covered.

Bean Lady Bug (*Epilachna corrupta*).—This insect is the most destructive bean insect from Colorado southward to Mexico. It is a small insect, 1/3 inch long, yellowish to brown-orange in color, with 16 small dots on the wing covers. Both grubs and beetles devour all portions of the plants. Eggs are laid on the undersides of the leaves and the larvae skeletonize them. There are one or two generations annually.

In the home garden hand picking may be resorted to, but in commercial plantings this is impracticable. Spraying with arsenate of lead double strength, 8 pounds of paste or 4 pounds of powder to 50 gallons of water, with 4 pounds of lime to prevent burning the foliage, will kill the insects. The underside of the leaves must be sprayed. Brushing them off on the ground causes many of them to perish.

Bean Thrips (*Heliothrips fasciatus*).—In the far west this insect sometimes injures the bean crop quite seriously. The adult insect is about 1/25 inch long, grayish-black, in color. Infested leaves of the bean plant turn pale and drop off. The pod takes on a silvery-white appearance.

This insect is seldom injurious enough to justify special control measures. If the plants are kept in a thrifty condition they can usually withstand the attack, but when necessary to spray, nicotine sulphate, 40 per cent, 1 part to 800 parts water, to which soap has been added will control this insect. The spray should be applied to the underside of the leaves.

Bean Aphis (*Aphis rumicis*).—The bean aphis is a small black plant louse, widely distributed throughout this country, but is especially serious in California. The insect passes the winter in the egg stage on various cultivated shrubs. It attacks many vegetables and several common weeds. Spraying with nicotine sulphate, as suggested for the thrips will keep the aphis under control.

Bean Fly or Seed-corn Maggot (*Phorbia fusciceps*).—The adult fly is about the size and appearance of the house fly. The larva is a small, whitish maggot which tunnels in the seeds, sprouts and stems of the plant underground and in the stalks above. Applying corrosive sublimate as described for the cabbage maggot would probably aid in controlling this pest.

Harvesting.—Snap beans are usually harvested before the pods are full-grown and while the seeds are small. Most varieties get tough and stringy if left on the plants until the seeds develop to full size. Picking is

done entirely by hand and the amount of labor required restricts large scale production to localities having an abundant supply of labor which can be had at any time.

After picking string beans they should be sorted to pick out diseased, broken and injured pods. They are then packed in hampers, baskets or boxes. Half-bushel, bushel and half-barrel hampers are used quite commonly for shipping string beans from the South. The round stave bushel basket is used in some sections. The package should be well-filled by shaking the basket as the beans are being packed.

When beans are transported long distances during warm weather they are shipped in refrigerator cars.

Harvesting Dry Beans.—Dry beans are harvested as soon as a large percentage of the pods are fully matured and have turned yellow. Most varieties do not ripen evenly hence it is desirable to watch the field and to begin harvesting before the lower pods get dry enough to shatter. Some varieties shatter more than others. Teparies shatter very badly and Red Kidney drops its seed if allowed to remain standing until the pods are fully dry.

Small areas of dry beans are pulled. When grown on a large scale bean harvesters are commonly used. These machines are equipped with cutting bars which cut off the plants below the surface of the ground. Guard rods, attached above the cutting bars, move the bean plants after they have been cut. Two rows are usually cut at one time and the plants are thrown together into one row. The vines are left in the windrow, or thrown together into small piles and left for several days to cure. If the vines are still green when harvested they should be left in the windrow until they become fairly dry. After curing for awhile in the windrow or in small piles they are hauled to the barn where they are stored until they are threshed. Formerly beans were stacked in small stacks in the field, but this practice is seldom followed in the main bean-growing sections of the eastern portion of the United States at the present time. In sections of the West they are stacked in small stacks (four or five wagon loads) although larger ones are sometimes used. In California the beans are cured in small cocks similar to those used in curing hay.

Threshing.—Beans are commonly threshed with machines similar to grain threshers. The common type of thresher used for beans has two cylinders and these are run at lower speeds than is common in threshing wheat, rye, etc. Grain threshers are sometimes used, but they are unsatisfactory, even when the speed is reduced to 300 or 400 revolutions per minute. Such machines should be further changed by removing all but one row of concave teeth and one-half of the cylinder teeth.

The flail is still used in some places where only a small quantity is to be threshed. In California disc rollers, pulled by unshod horses, are sometimes used for threshing beans. A threshing floor is prepared by

wetting and rolling a piece of adobe soil until it is smooth and hard, or a heavy canvas may be used. A deep layer of cured vines is then placed on the floor and after being run over with the roller until the beans are separated from the pods the vines are forked off and the process is repeated until several tons of beans have accumulated. The beans are then cleaned in fanning mills.

The combined harvester and thresher is also used to some extent in California. The beans are left in the windrow until thoroughly cured, when they are picked up by the movable threshing machine driven by its own power or pulled by a tractor.

SCARLET RUNNER OR MULTIFLORA BEAN

The Scarlet Runner (*Phaseolus multiflorus*), also called Dutch Case Knife, is probably a native of central America or South America, although it was formerly supposed to have been indigenous to Asia. In America it is grown mainly as an ornamental climber; the spikes or rich scarlet flowers and the deep green foliage makes it one of the most showy and attractive plants. In Europe this bean is used as food. The tender, green pods only are eaten in some localities, while in others the green and dry seeds are used.

The plant grows 12 feet or more in height and requires 115 to 120 days to mature its seeds. In germinating the Scarlet Runner differs from other species of Phaseolus in that the cotyledons remain in the ground and the germination is known as hypogeal. The plant produces a thickened root somewhat like the Dahlia, though smaller.

LIMA BEAN

Lima beans are important in the warmer parts of the United States, especially in the southern states and in California. They require a longer growing season than the common bean and are less hardy to cold. They are grown for use as green-shell beans and as dry beans, the latter industry being confined largely to southern California. According to figures furnished by the Lima Bean Growers' Association and quoted by Shaw and Sherwin (133) 82,850 acres were grown in 5 counties in California in 1910 and the yield was 1,160,000 sacks of 80 pounds each. Green lima beans especially of the bush type, are grown by market gardeners even in the northern states where the frost free period is 3½ to 4 months in duration.

History and Taxonomy.—Linnaeus believed that the lima bean was of African origin, but it is now known to be of tropical American origin, probably South America. Seeds have been found in Peruvian tombs and the plant has been found growing wild in Brazil. Sturtevant (157) states that in southern Florida, the lima bean is found growing spontaneously in abandoned Indian plantations. It is now widely distributed,

but since it requires a warm season it is not grown as much in northern Europe as in the United States.

There are two distinct types in cultivation in the United States, the sieva, Carolina or small lima (*Phaseolus lunatus*) and the large or flat lima (*P. lunatus* var. *macrocarpus*). Jarvis (79) gives the following descriptions:

Sieva Lima.—Plant annual, climbing or dwarf, frail, slender branches; leaflets moderately small, ovate, acuminate (one garden variety has linear-lanceolate leaflets), thin, smooth, glossy, dark green; flowers small, white or greenish-white, in axillary racemes; pods 2 to 4 inches long, ½ to ¾ inch broad, curved, well-defined point or spur, 2 to 4 seeded, green; seeds small, flat, subreniform, with distinct lines radiating from the hilum to the dorsal margin, variously colored.

Large Lima.—Plant perennial in the South, grown as an annual in the North, vigorous grower, climbing or dwarf; leaflets large, ovate or ovate-lanceolate, thick, stiff, slightly pubescent, dull green; pods large, 3 to 6 inches long, 1 to 1¼ inches broad, flat, frequently twisted, point or spur very short or wanting; seeds very large, usually very flat and reniform (the potato type quite turgid and subreniform), variously colored. It differs from the sieva type chiefly in being perennial (in the South), in making a larger growth, in being less hardy, later in season, and in having larger leaves and pods. Many strains, differing chiefly in season and size of pod, are in cultivation. The type of many of these modified forms is not well fixed and, for this reason, it is difficult to make accurate descriptions and comparisons.

Culture.—In general, the culture of both types of lima beans is practically the same as for the common or kidney bean. The lima, especially the large type, is less hardy to cold than the common bean and should not be planted until all danger of frost is over and the soil has become warm, since the seeds rot in cold soil. It also requires a longer growing season than the common bean. The pole varieties of large lima do not produce satisfactory crops in regions having less than 4 months' frost-free period, with warm weather, including warm nights for a considerable portion of this period. The main regions of production of lima beans are the southern states and California, the latter producing practically all of the dry limas. In the northern states the bush varieties of both the sieva and large lima beans are more generally grown than the climbing varieties. The large type is less hardy and requires a longer season than the sieva types, hence the latter is grown to a greater extent than the former in regions having a relatively short growing season. Climbing varieties, as a rule, require more time to mature than the bush or dwarf varieties.

In considerable portions of the northern border states the climbing varieties of large lima do not mature enough crop before frost in autumn when planted direct to the garden to justify growing. However, by

starting the seeds in pots, paper bands, berry boxes, or tin cans in a greenhouse or hotbed 3 or 4 weeks before it is safe to plant in the open, a satisfactory yield is often secured. Even by following this method the yield is low in regions having cool nights for a considerable portion of the growing season.

On light soils lima beans mature earlier than on heavy soils, hence in regions having a short growing season the lighter types should be selected, provided other conditions are favorable. Shaw and Sherwin (133) state that the difference in time of maturity is very great between sandy and clayey soils, and still greater between dry and moist soils. . .

It seems that the water supply of the soil more than the texture is responsible for the difference in time of ripening, as irrigation on light soils causes the same lateness of maturity. Thus, we find a tendency toward the perennial habit which the plant maintains under the humid conditions of the tropics.

Soils with much nitrogen tend toward late maturity, hence the limas ripen later on land which has been recently manured. On the other hand, the mineral elements tend toward early maturity. Limas require a richer soil than do the white kidney beans, the pole varieties require a richer soil than the bush varieties.

It may be said that all those soil conditions which tend to delay ripening tend also to increase yield of beans, provided, of course, the ripening period is not too long delayed.

It should be borne in mind that the above quotations are based on California conditions. In other regions, having a shorter growing season the yield may be much heavier on the lighter soils due to earlier maturity, therefore a longer bearing period.

Supporting the Vines.—Climbing varieties of lima beans are usually supported as mentioned for the climbing varieties of kidney beans, but in California, where they are grown for dry beans the plants grow on the ground. The climbing varieties of large limas are planted in rows 2½ to 3 feet apart with the seeds 6 to 12 inches in the row. The plants spread across the row and form a mulch which prevents rapid evaporation. Since the crop is grown in California during the dry season the vines sprawl on the ground with no injury to the pods.

Varieties.—As already mentioned there are two distinct types of lima beans, the sieva or Carolina and the large or flat lima, and both types include dwarf and climbing varieties. Among the varieties of dwarf sieva or Carolina beans, Henderson Bush Lima (Dwarf Sieva and Dwarf Carolina) is the best known. The best known climbing variety of the sieva type is Carolina or Sieva Lima, the "Butter Bean" of the South. Of the large lima (*P. lunatus* var. *macrocarpus*) two classes are recognized, the large-seeded or flat limas and the potato limas. Dreer's Bush Lima, Burpee's Bush Lima and Fordhook Bush Lima are well-known varieties of bush beans of the potato-lima class. Early Leviathan, King of the Garden, Challenger or "Potato" Lima and the Lewis Lima are

important varieties of climbing limas of the large type. The Lewis Lima is the most important variety grown in California for the dry seed.

The sieva lima beans are of value mainly because of their earliness since they are inferior in quality to the large limas.

Harvesting.—Lima beans, grown for use in the green-shell condition are picked by hand when the seeds have become nearly or quite full-grown, but before the pods turn yellow. Half-grown beans sell for a higher price than the full-grown ones, but the yield is lower and they are more difficult to shell. They are shelled by hand and usually are packed in quart berry boxes for market. The shelling is a very tedious, expensive operation and probably is the main factor limiting the production of green limas for market.

Dry lima beans are harvested in very much the same way as common field beans. In California a cutter is used which cuts two rows at a time and both rows are pushed together in the middle. The vines are left in the windrows for a few hours and then piled by hand with pitchforks. Three windrows are commonly brought together in one row of piles. These piles are 4 or 5 feet in diameter on the ground and 3 feet high. They remain in these piles until they are very dry, the time depending upon the weather and the maturity of the beans, but usually from 2 to 3 weeks.

Threshing.—Lima beans are threshed with a machine similar to a grain thresher. Shaw and Sherwin (133) give the following details regarding the machine used:

> . . . The bean threshers have three cylinders which are run at a speed of 280 to 350 revolutions per minute instead of a single cylinder running at a speed of 1,100 revolutions per minute. The cylinder teeth are set to run ⅝ inch from the teeth of the concave as against ⅜ in cereal threshers. The use of three cylinders with teeth set ⅝ of an inch from the teeth of the concave avoids an excessive breaking and splitting of the beans, which occur with the single cylinder running at high speed with teeth set close.

After threshing the beans are stored in warehouses until they are to be marketed, when they are recleaned. A machine is used for the recleaning and for separating the split beans from the whole ones. The beans are marketed in bags.

TEPARY BEAN

The tepary bean (*Phaseolus acutifolius* var. *Latifolius*) is probably native of southwestern United States and northern Mexico and was domesticated by prehistoric Indian races. Freeman (49) states that 47 distinct types have been isolated and grown at the Arizona Experiment Station.

Tepary beans are especially valuable in the arid regions of the Southwest and in similar regions of Mexico and elsewhere. They withstand extreme heat and dry atmosphere better than any other type of bean.

Freeman (49) writes as follows regarding the botanical relationship of the tepary:

> The tepary differs from both the kidney bean (*Phaseolus vulgaris*) and the lima bean (*Phaseolus lunatus*) in several marked botanical characters. The seeds are smaller, averaging .15 grams, while the kidney beans average .23 grams and the limas average .50 grams or more. When present at all the markings or flecks on teparies are much finer than on the other two. The seed coat of the tepary lacks the characteristic glossiness of the kidney bean.
>
> The length of the petioles of the first pair of aerial leaves is strikingly different in the tepary and in *Phaseolus vulgaris* and *lunatus*. Measurements of the mature petiole of the first pair or aerial leaves on a large number of seedlings of several varieties of each gave the average of the tepary 4.3 mm., for kidney beans 24.33 mm., and for the limas 43.7 mm. The first two pairs of aerial leaves of all three species are simple, but those of the tepary differ from the others in having truncate instead of cordate bases. They are also smaller and narrower . . .
>
> . . . The flowers of the tepary are smaller than those of the kidney bean, the wings are narrower in comparison with their length and the banner is more strongly reflexed in flower . . .

The culture of the tepary bean is not very different from that given the common kidney bean when grown under similar conditions. Freeman (49) suggests planting in rows 3 feet apart with the seeds spaced 6 inches apart in the furrow and covered to the depth of 4 inches, or else in hills 18 inches apart with two to four seeds in a hill. "It is important that the seeds be covered immediately following the opening of the furrow if quick germination and a uniform stand is to be insured."

Teparies are now grown in Arizona, New Mexico, and in sections of California, especially in the hot, dry interior valleys.

After a very careful study of the native beans of the Southwest, Freeman (49) gives the following summary:

> The peculiar climatic conditions of the semi-arid, sub-tropical Southwest are most favorable, usually, only to the varieties of crop plants which have been long grown in the region, or in similar regions.
>
> Among the Indians of the Southwest may be found varieties of corn, beans and squashes that have been grown within the present confines of Arizona for hundreds or perhaps thousands of years. Centuries of adaptation have therefore produced types well suited to withstand the extremes of heat and drought to which the climate often exposes them.
>
> Native-grown beans, the subject of this bulletin, are among the most successful of these acclimated crops.
>
> Two different types of beans have been collected from the Indians of southern Arizona, recognized by them as distinct and commonly known by the Mexican names, "Frijoles" and "Teparies."
>
> Botanical study has established the fact that these two types are different species. Frijoles belong to the group of common kidney beans (*Phaseolus*

vulgaris, Linn.); while teparies, heretofore unrecognized in horticultural literature and unknown to botanists except as a wild species, belong to that large and variable group described by Gray as *Phaseolus acutifolius.*

Frijoles, now grown in the Southwest, are probably descendants of varieties introduced by the early Spanish missionaries. Twenty-three distinct varieties have been tested at this Station, among the most promising of which may be mentioned the Pink bean, the Bayou, the Hansen, the Garaypata and the Red Indian.

Teparies, also grown by southwestern Indians, were probably not domesticated from the type form of *Phaseolus acutifolius* A. Gray, but from a larger, more robust, broad-leaved variety of the species such as was collected by Wright in a valley of Sonora as early as 1854, and described by Gray as distinct, but left unnamed by him probably on account of lack of material, which is now abundantly available.

The tepary (*Phaseolus acutifolius* A. Gray) is therefore added to the list of species of beans used as esculents and it is suggested that this form be called *Phaseolus acutifolius* var. *latifolius.*

The tepary was domesticated from wild plants growing in the canyons of the southwestern United States and northern Mexico by prehistoric Indian races. Being variable in the wild state it has responded during domestication by the production of many varieties. Forty-seven distinct types have been isolated and grown at this Station. Among the most promising sorts may be mentioned the White Tepary.

In the Southwest, by both irrigation and dry-farming methods of culture, these native-grown beans yield excellent crops—from 450 to 700 pounds per acre by dry-farming to 800 to 1,500 pounds under irrigation. Under all conditions, however, teparies have out-yielded frijoles, and in nine experiments herein reported, where these two crops have been compared, have averaged four times the productiveness of frijole beans.

The tepary is therefore recommended to the attention of southwestern farmers (1) as the variety of bean best adapted to an exacting climate, and (2) as a probable money crop available both to irrigators and to dry-farmers.

SOYBEAN

The Soybean (*Glycine hispida or Soja Max.*) is a native of southeastern Asia and has been cultivated in Japan and India since ancient times. Hundreds of varieties are grown in these countries and in China. In the extent of uses and value it is the most important legume grown in these countries. The soybean was first introduced into the United States as early as 1804, but it is only within the last fifteen years that it has become of much importance. It is now grown mainly for forage in this country, although there is interest in the crop for the manufacture of oil and for use of human food.

In Asiatic countries, especially China and Japan, the soybean is second in importance to rice as a food crop. Morse (100) gives the following uses for the soybean and the food products made from the seeds:

- Meal
  - Human food
    - Breakfast foods
    - Diabetic foods
    - Flour
      - Bread
      - Cakes
      - Muffins
      - Biscuits
    - Infant foods
    - Macaroni
    - Crackers
    - Milk
  - Stock feed
  - Fertilizer
- Oil
  - Industrial uses of various kinds
  - Food Products
    - Butter substitute
    - Lard substitute
    - Edible oils
    - Salad oils
- Dried beans
  - Soy Sauce
  - Boiled beans
  - Baked beans
  - Soups
  - Coffee substitutes
  - Roasted beans
  - Vegetable milk
    - Cheese
      - Fresh
      - Dried
      - Smoked
      - Fermented
    - Condensed milk
    - Fresh milk
    - Confections
    - Casein
  - Breakfast foods
- Green beans
  - Green vegetables
  - Canned
  - Salads

The soybean plants are used for green manure, for forage and for pasture.

The soybean has about the same climatic adaptations as corn. Morse (100) states that it is especially adapted to the cotton region of the United States and northward to the Ohio and Potomac Rivers. In the latter region the larger and later varieties, which give yields that make their extensive cultivation very profitable, can be grown.

Recent introductions of early maturing varieties from northern Manchuria mature profitable yields of seeds in the northern tier of states, while the later varieties can be grown for hay or ensilage.

In the lower sections of the Gulf Coast and in the Southwest where extreme hot weather prevails during the period when the pods are maturing the yield of seed is small.

The soybean is quite drought-resistant and but for the depredations of rabbits it would be a valuable crop in the semi-arid West.

Culture.—The time to plant soybeans depends upon the length of the growing season and the use to be made of the crop. In general the crop may be planted about the same time as corn, although in the South soybeans are planted as late as August. When grown for seed the crop is usually planted in rows about the same as common beans, but for hay or for green manure broadcast sowing is the common practice. Planting in rows is preferred by some authorities for all purposes.

The crop is harvested and handled about the same as cowpeas.

COWPEA

The Cowpea (*Vigna sinensis*) is probably a native of central Africa. Piper (115) reports that a wild plant differing little from the cowpea occurs throughout a large part of Africa. Hybrids of this plant and the cultivated cowpea are readily obtained. According to Morse (99) the cultivated cowpea consists of three main groups, the asparagus bean (*V. sinensis* var. *sesquipedalis*) the catjang (*V. sinensis* var. *cylindrica*) and the cowpea, each of which represents a group of varieties having much in common. The cowpea is the most important of the three groups.

On the history of the cowpea Morse (99) writes as follows:

> The large number and great diversity of cultivated varieties throughout Africa and over the southern half of Asia and the adjacent islands as well as the Mediterranean region of Europe indicate that the cowpea is of ancient cultivation for human food. It was early introduced in the Spanish settlements of the West Indies and was grown in North Carolina in 1714, probably coming from the West Indies. Its culture in Virginia was reported about 1775 and no doubt was quite general in the United States early in the nineteenth century.
>
> Without doubt, the cowpea is the *Phaseolus* mentioned by the old Roman writers. In Italy the Blackeye cowpea is still called by the same name as the kidney bean, namely "fagiolo," which is the Italian equivalent of Phaseolus. In East Africa both the wild and cultivated cowpeas are called "kunde," while in India, where the catjang is more extensively cultivated, the name "lubia," with many others is used. In America the cowpea was first known as "callivance" and later as "Indian pea," "southern pea," "southern field pea" and "cornfield pea." The first published record of the name cowpea was in 1798 and applied apparently to a single variety.

In the southern states the cowpea is often called "pea" and the garden pea (*Pisum sativum*) is called "English pea." The term pea is, however, incorrect since the cowpea is not a pea but a bean.

The cowpea was grown for human food in ancient times, especially in Africa, Asia and in parts of the Mediterranean region of Europe. While it is grown mainly for hay, ensilage, pasturage for all kinds of stock, and as a soil-improving crop in the United States it is used as human food in the southern states. The seeds are used as food both in the green-shell and in the dry condition and while all varieties are eaten to some extent the Blackeye and White varieties are the most popular. These two varieties are practically the only ones sold on the market for human food. "Blackeyed peas" are more common in the stores of the South than are dry beans.

The cowpea is of special importance to the vegetable grower of the South since this is the principal soil-improving crop grown. It fits in well with the usual cropping system since it can be grown during the summer after the spring or early summer vegetable crop is harvested and before planting the winter vegetables.

Culture.—The cowpea is a warm-weather crop and is, therefore, grown mainly in the South, although it is grown with success in the southern parts of Ohio, Illinois, Indiana and New Jersey and in parts of Michigan and other northern states. It is injured by the very lightest frost.

Cowpeas thrive on all types of well-drained soils.

When planted for forage the seed is usually sown broadcast or in drill rows 6 to 8 inches apart, but for production of seed, planting in rows 3 feet apart, with the seeds 2 to 3 inches apart in the row gives better results. With the row method 30 to 40 pounds of seed will be required; when sown broadcast about 90 pounds of seed to the acre will be sufficient.

When used as food cowpeas are picked by hand or harvested with a mowing machine and threshed in the various ways mentioned for beans. Of course, they are picked by hand when used in the green-shell state.

PEAS

Peas are grown in most home gardens and they also enter into market gardening, trucking and canning. A large part of the commercial crop is grown for canning and it ranks third in importance of the vegetables canned, being exceeded in value by tomatoes and sweet corn.

Importance.—According to the Census Report 103,686 acres of peas, were grown for sale in the United States in 1919 and the farm value of the crop was $7,164,988. Slightly over one-half of the total acreage was produced in two states, Wisconsin with 36,742 acres and New York with 17,440 acres. Other important states in 1919 were California with 8,246 acres and New Jersey with 4,241 acres. All of these are important canning states.

History and Taxonomy.—The pea (*Pisum sativum* Linn.) is probably a native of Europe and possibly of northern Asia. Its culture goes back to a remote period, having been grown by the ancient Romans and Egyptians. Peas came to America with the first immigrants and are now grown practically everywhere.

Dry peas are either smooth or wrinkled, the former type excels in hardiness, but the latter is better in flavor. The wrinkled peas are sweeter and are often called "Sweet peas."

Peas vary greatly in character of vine. Some are dwarf, some half-dwarf and others tall. The shortest varieties are not much over 1 foot tall, the half-dwarf grow to a height of 2 to 3 feet on rich soil. The field pea has been considered by some botanists as belonging to a different species from the garden pea and was called *Pisum arvense*, but this distinction is now generally abandoned. It is, however, considered as a botanical variety by some authorities and is given the name *P. sativum* Var. *arvense*.

Soil Preferences.—Peas are grown on a great many kinds of soils from the light sandy loams to the heavy clays. For a very early crop a sandy loam is desired, but for large yields, where earliness is not an important factor, a well-drained clay loam, or a silt loam is preferred. Good drainage is essential, for the pea plant will not thrive on soggy or water-soaked land. The soil should, however, be retentive of moisture, especially for the late varieties, or for early varieties planted late in the spring or early summer.

Thorough preparation is important for peas as for other vegetables. It is especially important where the seed is to be sown broadcast or planted with a grain drill since under this method no cultivation is given the crop. Fall plowing is important for the early crop since planting is often greatly delayed when the land must be plowed in the spring. The seed bed should be well pulverized to the depth of 3 or 4 inches. When the crop is grown for the cannery effort is made to leave the surface smooth by rolling either before or after planting, or both, as a rough, uneven surface interferes with the use of the mower in harvesting the peas.

Fertilizers and Manures.—Commercial fertilizers are usually applied to the land for peas, the amount and kinds depending upon the soil and the purpose for which the crop is grown. On light soils a complete fertilizer, containing about 2 per cent nitrogen, 8 to 10 per cent phosphoric acid and 4 to 8 per cent potash, is often applied at the rate of 500 to 1,000 pounds to the acre when the crop is grown for the general market. When grown for canning a large amount of fertilizer is seldom profitable even though the yield is increased. In most regions where peas are grown for the cannery, the soil is fairly rich and the crop is grown in rotation with general farm crops and only a small amount of fertilizer is necessary. Some growers apply 300 to 500 pounds of a fertilizer analyzing 1 to 2 per cent nitrogen, 8 per cent phosphoric acid and 4 to 5 per cent potash. Others use only phosphoric acid. Authorities generally agree that phosphorus is the element most needed.

Manure is seldom applied to the land for peas although it is quite generally used in the rotation. A common practice is to apply the manure to the crop preceding peas and this is considered preferable to applying it to the soil the year the pea crop is grown. Fresh stable manure is liable to produce a rank vine growth at the expense of pods and for this reason it is seldom used on peas. Where a clover sod is turned under or where a green-manure crop precedes peas, manure is not needed.

Inoculation.—Considerable difference of opinion exists regarding the importance of inoculating pea seed with nitrogen-fixing bacteria. Experiments have not given conclusive results, although it is generally recommended that inoculation be given when peas are to be planted on

new land. Field tests in Wisconsin (48) show that on a heavy, rich clay loam, slightly acid and cropped to peas for years, inoculation did not increase the yield. On a rich, silt loam, unlimed and acid, not previously cropped to peas, inoculation increased the total yield of plants, of peas and also the percentage of nitrogen. Inoculation of neutral, rich silt loams, also gave favorable results. Some injurious results from inoculation have been reported. The injury was probably due to the development of injurious organisms due to the wetting of the seed in applying the inoculating material.

Planting.—Smooth peas, represented by the Alaska, are hardy and may be planted as soon as hard freezes are over, or as soon as the land can be prepared in most sections of the North. Wrinkled peas are not so hardy as the smooth-seeded type, but they will withstand light frosts and the seeds will germinate at relatively low temperatures, hence they may be planted as soon as hard frosts are past. None of the types of peas thrive during very hot weather, hence they are grown as winter and spring crops in the South and as spring and early summer crops in most sections of the North. In a few favored localities the crop does fairly well during midsummer, although, even in these regions, peas are not a sure crop. In the regions in which the pea crop thrives during midsummer the temperature is relatively low and the rainfall relatively high. The climate in such regions is usually modified by high elevation or by the presence of a large body of water.

For a succession of edible green peas it is necessary to make several plantings at intervals of 10 days to 2 weeks, or to plant early, medium and late varieties at about the same time. It is a common practice to plant seed of the Alaska variety as soon as the ground can be worked, then later to make plantings of early, medium and late wrinkled varieties, or to make several plantings of the same variety at the proper intervals.

The depth of planting should be determined by the character of the soil and the moisture conditions. On fairly moist clay soils a depth of 2 or 3 inches is sufficient, while on sandy soils a covering of 4 inches is none too much when the soil is fairly dry.

The amount of seed planted depends largely upon the method of growing, but to some extent also upon the size of the seeds. When planted in rows 2 to 3 feet apart about 1½ to 2½ bushels are required to plant an acre, the larger amount being used when planting in double rows. When the crop is planted with a grain drill the usual rate of planting is about 4 bushels to the acre, athough it varies from 3 to 5. This method is almost universally used in growing peas for the cannery and is employed to some extent for the market crop.

Planting by hand is commonly practiced in home gardens and hand seed drills are usually employed when planting small areas for market.

For large areas the grain drill is commonly used. By stopping up alternate openings the rows are made far enough apart for cultivation while the vines are small.

Cultivation.—Peas grown in the home garden are practically always planted in rows and clean cultivation is given until the vines interfere with the operation. A large part of the crop grown for city markets is also planted in rows far enough apart to allow for cultivation. A small percentage of the market crop and practically all of the canning-crop peas are sown so thickly that cultivation is not possible. On fairly clean land cultivation is not necessary provided the planting is heavy enough to make a mat of vines over the entire area. Where weeds are very troublesome either peas should not be grown or they should be planted so that cultivation can be given while the plants are small.

Supporting the Vines.—Tall-growing varieties of peas are usually supported when grown in the home garden and to a very limited extent in commercial plantings. Brush stuck into the ground along the row or between two rows, when the double-row method of planting is followed, is an old method of supporting the vines. Wire netting fastened to a line of stakes, driven into the ground along the row or between the double rows, makes an ideal support for the vines. Three or four lines of twine fastened to small stakes make fairly good supports. This method is followed to some extent in the South.

Supporting the vines is not as common as it was formerly, even in home gardens. In commercial pea growing supports have gone out of use almost entirely in the North. The extra labor and expense do not seem to be justified.

Varieties.—The earliest varieties of peas are the smooth-seeded type, and Alaska is by far the most important variety of this type. It is poor in quality, but it is popular because of its earliness and small size. As a canning pea it is grown to a greater extent than all other varieties combined.

Of the wrinkled peas, Gradus, Thomas Laxton, Notts' Excelsior, Blue Bantam and American Wonder are dwarf or half-dwarf early varieties but not as early as the Alaska. The dwarf and half-dwarf varieties are more popular than the tall varieties with home gardeners since they do not take up as much space when grown without supports. The most popularl medium and late varieties are Telephone, Telegraph, Champion of Engand, Horsford's Market Gardener, Advancer, Admiral and Surprise. These usually produce a larger yield than the early varieties.

A type of pea grown for its pods as well as for the seeds is known as Sugar pea. The pods are thicker, and larger than those of the common varieties. Early Sugar and Mammoth Sugar are the best known varieties of this type. The sugar pea is not popular in this country.

Many of the varieties mentioned are grown for the canning factory as well as for home use and for market, but the Alaska is by far the most important variety for canning. To be a good canning pea a variety (1) must be productive, (2) must ripen its pods uniformly, (3) have all pods usable at one time, that is, none must be too ripe or too immature and (4) must have the seed green after processing. Quality is of importance but the variety must meet the four requirements enumerated. When peas were picked by hand the second and third requirements were not so important as now. The viner a machine used for shelling peas, has had a decided influence on the list of varieties used for canning.

Figures obtained by the Food Administration on canners' operations for the year 1917 quoted by Shoemaker (136) indicate that the following varieties were used in the percentages shown:

Smooth peas:		
Alaska		55
Wrinkled peas:		
Horsford Market Garden	18	
Advancer	8	
Little Gem	1	
Perfection (Davis)	1	
Admiral	13	
Surprise	2	
All others	2	
Total, wrinkled peas		45

The Alaska holds its position because it is hardier, a more reliable cropper than the wrinkled sorts, and probably because the consuming public has associated quality with small size. The Alaska is a small-seeded variety, but it is very inferior in quality to the wrinkled peas. There is a tendency toward a relative increase of wrinkled peas because the public is becoming educated as to quality in canned peas.

Diseases.—The most important diseases of peas are mildew, leaf- and pod-spot, stem-blight and root-rot. Mildew appears as a gray-white mold on the leaves and pods. Leaf- and pod-spot appear as dark spots on the leaves and pods and spread to the seed. Root-rot is a dry rot at and beneath the surface of the soil. It causes a reduced growth or even entire wilting of the plant.

Crop rotation and the use of disease-free seed are preventive measures recommended. No satisfactory measures have been found for controlling these diseases after they appear.

Pea Aphis.—The pea aphis is the only serious insect pest affecting the growing crop of peas. This insect is one of the larger species of plant lice. It is pea-green in color. It attacks the young vines, the insects gathering in clusters near the tips and sapping the life out of the plants. Spraying with nicotine sulphate, to which whale oil soap has

been added is recommended, but it has not been found practicable on a commercial scale. Planting early so that the crop is mature before the lice become abundant, is the surest way to avoid loss.

Pea Weevil (*Bruchus pisorum*).—The pea weevil is a serious enemy of the field and garden pea. It is now found in nearly all parts of the world, but does comparatively little damage in the colder portions of Europe and North America. The eggs are deposited on the surface of the pods. In the vicinity of Washington, D. C., a considerable portion of the weevils mature and leave the seeds in the latter part of the summer, but farther north and in high altitudes the adult remains in the seed until the following spring. The weevil passes the winter in the adult stage, either in secluded spots in fields and buildings or in the pea itself. The weevil has only one generation a year and does not reproduce in dry seed.

Cleaning up the refuse in the field helps to reduce the number of beetles. Fumigation with carbon disulphid will destroy the weevils in the stored peas.

Cost of Production.—The cost of producing peas varies between wide limits and there is very little accurate data available on the subject. Norton (109) has, however, reported on a study made on canning-factory peas grown in New York State in 1920. Records were secured on 262 farms growing 1,468 acres, with an average yield of 2,246 pounds to the acre. The data is given in Table XLIX.

Table XLIX.—Average Cost of Producing an Acre of Peas on 262 New York Farms Growing 1,468 Acres in 1920
(Table 5 *Cornell Bull.* 412)

Item	Quantity per acre	Cost per acre	Per cent of total cost
Seed	4.0 bu.	$15.71	22.0
Fertilizer	164.0 lbs.	2.82	3.9
Manure charged to peas	2.8 tons	5.66	7.8
Lime charged to peas	52.0 lbs.	0.10	0.1
Labor growing peas:			
Human	15.8 hrs.	6.93	9.6
Horse	37.5 hrs.	9.18	12.7
Use of equipment	37.5 hrs.	3.07	4.3
Use of tractor	0.3 hr.	0.61	0.8
Use of automobile and truck		0.03	
Miscellaneous growing expenses		0.05	0.1
Interest on growing costs		0.61	0.8
Use of land		8.95	12.4
Total growing cost		$53.72	74.5

Table XLIX.—Average Cost of Producing an Acre of Peas on 262 New York Farms Growing 1,468 Acres in 1920—*Continued*
(Table 5 *Cornell Bull.* 412)

Item	Quantity per acre	Cost per acre	Per cent of total cost
Labor harvesting peas:			
Human	21.8 hrs.	$ 9.10	12.6
Horse	26.2 hrs.	6.43	8.9
Use of equipment	26.2 hrs.	2.16	3.0
Use of automobile, truck, and tractor		0.17	0.2
Miscellaneous harvesting expenses		0.36	0.5
Interest on harvesting costs		0.20	0.3
Total harvesting cost		$18.42	25.5
Total cost of crop		$72.14	100.0
Value of ensilage		2.73	3.8
Net cost of shelled peas		$69.41	96.2
Shelled peas sold to factory	1.123 tons	$90.34	
Price received per ton		$80.44	
Cost per ton		$61.81	

The average yield of peas per acre on the 262 farms, from which records were secured in 1920, was greater than the average normal yield for a period of years. Where the yield of peas was less than 1,800 pounds to the acre (81 farms, 408 acres), with an average yield of 1,492 pounds per acre the average cost per acre was $66.92 and the average cost per ton was $86.96. With yields between 1,800 and 2,500 pounds per acre, averaging 2,138 pounds (101 farms, 564 acres), the cost was $72.91 per acre and $65.41 per ton. Where the yield was 2,500 pounds or more to the acre (80 farms, 496 acres), averaging 2,988 pounds the cost per acre was $75.71 per acre and $48.66 per ton. The average return per hour of human labor was $0.31, $0.83 and $1.59 respectively.

Norton (109) shows that as the acreage of peas per farm increased the cost of production per acre and per ton decreased. The acres grown per farm did not affect the cost per acre before harvest, but the cost of harvesting was considerably less on farms growing larger acreages:

> This was in spite of the fact that these farms had higher yields than the farms in the other groups. Part of this lower cost is due to the larger acreages grown on farms nearer to the viner.

The larger yield per acre secured on the farms growing the larger acreages was probably one of the chief reasons why peas were so exten-

sively grown. Table L shows the relation between the acres of peas per farm and cost of production.

Table L.—Relation between Acres of Peas per Farm and Cost of Production, 262 Farms, 1920
(Table 35 Cornell *Bull.* 412)

Acres of peas per farm	Number of farms	Average number of acres per farm	Average yield per acre, lb.	Cost per acre		Total cost		Average distance to viner, mi.
				Growing	Harvesting	Per acre	Per ton	
Less than 6	162	3.2	2,136	$55	$21	$76	$71	2.3
6–10	73	7.2	2,274	53	19	72	63	2.2
Over 10	27	15.4	2,346	54	15	69	59	1.5
All farms	262	5.6	2,246	$54	$18	$72	$64	2.0

Harvesting.—Peas grown for home use and for the general market are picked by hand and this is the most expensive operation connected with the growing and handling of the crop. Growers estimate that the cost of harvesting the crop is about one-half of the total cost of production. In other words, the cost of picking equals the combined costs of seed, preparation of the soil, fertilizers, manures, use of land, and planting.

In picking peas by hand it is the practice of some growers to make two or three pickings, while others make only one picking. In the latter case the vines are pulled and all the filled pods are picked off. It costs less to pick an acre of peas by the latter method but the quality of the product is better and the yield higher when two or more pickings are made.

Peas for the cannery are harvested with a mowing machine. The vines are cut as near the ground as possible. They are then loaded onto wagons and hauled to a viner where the peas are shelled and separated from the vines and pods by the use of machinery. Mowing machines are often equipped with special devices which lift the vines so that they can be cut close to the soil. These vine lifters are large-fingered attachments which are placed on the cutting bar. Some machines are equipped with "swathers" or "windrowers" which roll the vines to the center of the swath. A hay loader may be used in loading the vines from the windrow.

The time for harvesting peas is determined largely by the appearance of the pods. These should be well-filled with young, tender peas, changing in color from a dark to light green. It is the aim to harvest the peas while they are still in prime condition but without sacrificing yield. If harvested too early the yield is light and if delayed too long the quality is poor although the yield is heavy.

A yield of $\frac{3}{4}$ to 1 ton of shelled peas to the acre is considered fairly satisfactory. The average yield per acre in the United States was 1,600 pounds, 2,000 pounds, 1,600 pounds and 2,000 pounds in 1917, 1918, 1919 and 1920 respectively. As a rule the yield of smooth peas is smaller than that of the wrinkled varieties.

Packing for Market.—Peas are packed mostly in baskets or hampers for shipment to distant markets. The round stave basket, holding one bushel is becoming popular as a market package in some sections. Some shippers prefer a smaller package, such as the 16-quart hamper. Burlap bags were used to a large extent in New York, but they are not satisfactory containers and their use has been discontinued. The pods were often badly bruised in the bags and then decay set in with the result that the peas often reached the market in a heated, decayed condition.

Peas are shipped by express or by fast freight. When shipped long distances refrigerator cars should be used as the peas heat quite readily and deteriorate in quality and appearance.

CHAPTER XXV

SOLANACEOUS FRUITS

Tomato	Pepper
Eggplant	Husk Tomato (Physalis)

The solanaceous fruits, tomato, eggplant, pepper and husk tomato all belong to the same botanical family, Solanaceae. All of these are tender plants grown as annuals and produced for their fruits. The methods of culture for all of them are similar. They are grown from seed sown in a special seed bed, usually under cover and are often transplanted prior to setting in the garden or field. From the standpoint of both the relationship and cultural requirements they are grouped together for discussion.

TOMATO

The tomato is one of the most popular vegetables, as well as one of the most important. It is grown in nearly all home gardens, and by a large percentage of market gardeners and truck growers. It is produced as a forcing crop in greenhouses of the North at the same time it is being grown in the open in Florida. As a canning crop it takes first rank among the vegetables.

Few products lend themselves to as great a variety of uses as the tomato. Carver (21) gives 115 ways of preparing the tomato for the table. It is used cooked and raw, and is made into soups, salads, conserves, pickles, catsups, sauces and many other products. It is served baked, stewed, fried, and as a sauce on various foods.

Statistics of Production.—The Bureau of the Census gives the acreage of tomatoes grown for sale in the United States in 1919 as 316,399 acres and the value $38,675,496. The average value per acre was $122, which is considerably above the average. Over 75 per cent of the acreage of tomatoes grown in the United States in 1919 was produced in 10 states as shown in Table LI.

A large part of the crop in all of these states except Florida, was grown for the cannery. The high value per acre in Florida is due to the fact that the crop is grown and marketed during the winter and spring when the price is high. The low value per acre in Maryland, Delaware and Virginia was due to very low yields in 1919. Disease was very serious in these states and in New Jersey in 1919 and the yields were much below the average.

Table LI.—Acreage, Total Value and Value per Acre of Tomatoes Grown in the Ten Leading Producing States in 1919

State	Acres harvested	Value of product	Average value per acre
Maryland	58,083	$ 4,286,591	$ 74
New Jersey	36,986	3,803,193	103
California	31,410	3,579,115	114
Delaware	22,797	1,213,575	53
Virginia	22,380	1,689,686	75
Indiana	20,790	1,990,374	96
Florida	18,089	4,103,929	227
New York	13,417	2,378,858	177
Ohio	10,870	2,154,259	198
Missouri	10,346	1,099,618	106
United States	316,399	38,675,496	122

History.—The tomato is a native of tropical America and is supposed to have been eaten by wild tribes of Mexico who called it tomati. The name tomato is of South American origin and is derived from the Aztec word zitomate, or zitotomate and is applied to the fruit of both the common tomato and that of the Husk tomato. Both of these types were grown and highly prized by the natives before the discovery of America.

According to Sturtevant (157) the earliest mention of the tomato in literature was by Matthiolus in Italy in 1554. It is probable that they were known in Germany, France, Belgium and England prior to 1600. From descriptions and cuts found in old literature it seems fairly certain that large, smooth fruits, similar to some of the varieties now grown, were known long before they came into general use in America. It is probable that they were cultivated in Europe mainly for ornament and as a curiosity until about the middle of the eighteenth century. Miller (Sturtevant's notes) reports that they were used in soups in England during the latter half of the eighteenth century.

The first mention of the tomato as being grown for culinary use in America was by Jefferson in 1781. McMahon (94), 1806, speaks of the tomato as being held in high esteem for culinary purposes in America. In 1812 tomatoes were regularly quoted in the market of New Orleans. Thorburn (Gard. Kal. 1817) gives cultural directions for growing the tomato. It was not until about 1835 that the tomato became quite generally cultivated for culinary purposes in America and even at that time there was considerable prejudice against its use. The tomato growing industry made rapid strides during the latter half of the nineteenth century.

Taxonomy.—The tomato belongs to the nightshade or Solanaceae family and to the genus *Lycopersicum.* The genus comprises a few species of annual, or short-lived perennial, herbaceous plants. The many branches are procumbent or partially erect. The stems are round, soft, brittle, and hairy when young, but become angular, hard and almost woody when old. The leaves are alternate, 5 to 15 inches long, odd-pinnate, with seven to nine short-stemmed leaflets. The flowers are borne in clusters, located on the stem between the nodes. The flowers are small; corolla deeply five-cleft, yellow, the petals recurving and broadly lanceolate; calyx with five long, linear or lanceolate sepals, which are shorter than the petals at first, but increase in size as the fruits mature. The stamens are five in number and are borne in the throat of the corolla; anthers large, borne on short filaments. The fruit is a two to many-celled berry with fleshy placentae and many small kidney-shaped seeds covered with short stiff hairs.

Most authorities recognize two distinct species, *L. esculentum* and *L. pimpinellifolium,* with four or five botanical varieties under the former. Others believe that the pear and cherry tomatoes represent true species rather than botanical varieties belonging to the species, *L. esculentum.* Tracy (167) gives the following as true species, *L. pimpinellifolium,* currant or grape tomato; *L. cerasiforme,* cherry tomato; *L. pyriforme,* pear tomato; and *L. esculentum,* the common garden tomato including nearly all varieties grown in the United States. Bailey (6) classified tomatoes into two species *L. pimpinellifolium* and *L. esculentum* with the following botanical varieties under the latter:

var. *commune,* Common tomato
var. *grandifolium,* Large-leaved tomato
var. *validum,* Upright tomato
var. *cerasiforme,* Cherry tomato; and var. *pyriforme,* Pear tomato.

Whether the types known as pear and cherry tomatoes are species, or botanical varieties the fruits are readily distinguished from the common garden tomato.

Soil Preferences.—The tomato is grown on nearly all types of soils and there is difference of opinion as to which type is most desirable even under the same climatic conditions. McCue and Pelton (92) report on a questionnaire sent to a large number of farmers in Delaware. Out of 273 replies 127 farmers preferred a clay loam, 105 a sandy loam, 18 any good rich soil, 7 no preference, 7 prefered a loam, 6 clay and 3 prefered sandy land. For an early crop a light soil such as a fine sand, or a sandy loam is preferred, while for the main crop, where large yields are the most important, a rich sandy loam, or a good clay loam is desired by most growers. Some authorities consider a rich sandy loam, with a

well-drained clay subsoil, as the best soil for tomatoes even where large yield is the prime consideration.

Authorities are agreed that a well-drained soil is essential for high production. It is essential, however, that the soil be retentive of moisture, especially where the crop is grown throughout the main portion of the growing season, as in nearly all sections of the North.

Thorough preparation of the soil is important for the tomato as for most other vegetable crops.

Fertilizers and Manures.—The kinds and amounts of fertilizers and manures that may be used with profit depend upon the character and richness of the soil, the length of the growing season and the purpose for which the crop is grown. On fairly rich soil little, or no, fertilizer need be applied, although a light application of phosphorus usually is profitable. Where the growing season is short a small amount of complete fertilizer, even on rich soil, is advisable in order to hasten ripening. The nitrogen should be in a readily available form to give the plants a good start. The mineral elements are important in hastening ripening. Large applications of fertilizers may be profitable in growing tomatoes for an early market and unprofitable when growing for a late market or for the cannery. Dacy (36) found that on a shaly, clay loam in West Virginia 400 pounds of a high-grade fertilizer gave greater net profits than 600 pounds of the same material. Rosa (125) shows that 250 pounds of a 5–8–7 fertilizer, and 250 pounds of 16 per cent acid phosphate gave higher net gains than 8 tons of manure, although the yield on the manure plats slightly exceeded the yield from either of the other two treatments. The results reported by Rosa were secured in ten tests in Missouri in 1919. These covered a wide range of conditions. Results of 5 years' experimental work in Ohio (163) show larger yields from 800 pounds of 14 per cent acid phosphate, 100 pounds muriate of potash and 320 pounds of nitrate of soda than from 16 tons of manure, and about the same yield as 16 tons of manure supplemented with 400 pounds of acid phosphate. (See Chapter III). The net returns were considerably higher from the fertilizer treatment than from the manure. McCue and Pelton (92) report that 1,200 pounds of a 4–8–10 fertilizer produced a larger yield and a considerably larger percentage of ripe fruit than 20 tons of manure. The average yields for 4 years 1909 to 1912 were 10,979 pounds per acre with no fertilizers, 17,339 with 600 pounds 4–8–10, 23,279 with 600 pounds of 4–8–10 and 20 tons of manure, 17,887 with 250 pounds of acid phosphate and 120 pounds of muriate of potash, 13,342 with 250 pounds acid phosphate alone, 25,886 with 1,200 pounds of 4–8–10 and 15,248 pounds of tomatoes with 120 pounds of muriate of potash. The nitrogen in the complete fertilizer was in tankage. In this experiment in Delaware all three of the important elements were of value. Potash alone increased the yield more than phosphorus alone.

Practically all authorities agree that phosphorus is the element most needed on a large percentage of soils. Most of the experiments show the importance of this element, although on the lighter soils both nitrogen and potash are usually needed, and generally are profitable when used in moderate amounts.

Rosa (125 and 126) recommends for Missouri a 2–12–2 fertilizer for poor soils, a 3–12–0 mixture for soils of medium fertility and 16 per cent acid phosphate alone for rich soils, or those on which manure or legumes has been recently used. Brown (18) recommends 500 to 1,000 pounds of 2–12–6 fertilizer for tomato soils in Indiana. Dacy (36) suggests an application of 400 pounds of a 3–8–10 fertilizer for the shaly, clay soils of West Virginia. McCue and Pelton (92) recommend a fertilizer containing 3 to 5 per cent nitrogen, 5 to 7 per cent phosphoric acid and 8 to 10 per cent potash. They state, however, that the average amount of fertilizer used per acre in Delaware is 550 pounds of a 2–8–5 mixture. "Stable manure is most economically applied to the land for some other crop."

Nearly all of the above recommendations were made as a result of fertilizer experiments carried on in the various states. It should be borne in mind that the experiments were conducted on different types of soils and under different systems of farming and these account, in a large measure, for the divergent recommendations.

On light soils a complete fertilizer should be used in amounts ranging from 400 to 1,200 pounds depending upon the richness of the soil and the purpose for which the crop is grown. When tomatoes are grown for the cannery, in rotation with general farm crops, the fertilizers suggested by Rosa should give profitable returns when applied at the rate of 200 to 500 pounds per acre. Manure, except in small quantities, is not to be recommended on account of the expense and because it can be more profitably used on other crops. It would ordinarily be better to apply manure to the crop preceding the tomatoes rather than direct to the tomato crop. Large quantities of fresh manure delay ripening which is an important factor in the North.

In general the best time to apply fertilizers is before the crop is planted. Rosa (125) gives the results of experiments conducted for three years in Missouri and in each of these years a higher yield was secured from applying the fertilizer before setting the plants than when applied 10 days after planting. Applying in the row gave a slight increase over broadcasting the fertilizer. With small amounts (less than 500 pounds) applying in the row may be the best method to use, but for larger amounts broadcasting would probably give as good results.

Vegetation and Reproduction.—In agricultural and botanical literature statements are frequently made to the effect that highly vegetative plants are unfruitful. Many references deal with a relationship between

plant responses and the availability of the raw materials. Klebs (84) has brought together the results of many investigations which show that the environmental conditions largely determine whether a plant shall remain in a vegetative condition or become sexually reproductive. The controlling factors were found to be a decrease in the supply of raw materials (especially nitrogenous materials) and an increase in the intensity of light.

Kraus and Kraybill (86) have reported results of a careful study of the problem of vegetation and reproduction in the tomato. They used chemical analysis to reveal the internal conditions which correspond to certain experimental treatments, and to the observed behavior of the plants. In the introduction to their paper the following appears:

Four general conditions of the relation of nitrates, carbohydrates, and moisture within the plant itself, and the response apparently correlated therewith, will be discussed. These are:

1. Though there be present an abundance of moisture and mineral nutrients, including nitrates, yet without an available carbohydrate supply vegetation is weakened and the plants are non-fruitful.

2. An abundance of moisture and mineral nutrients, especially nitrates, coupled with an available carbohydrate supply, makes for increased vegetation, barrenness and sterility.

3. A relative decrease of nitrates in proportion to the carbohydrates makes for an accumulation of the latter, and also for fruitfulness, fertility and lessened vegetation.

4. A further reduction of nitrates without inhibiting a possible increase of carbohydrates, makes for a suppression both of vegetation and fruitfulness.

Among the conclusions of Krause and Kraybill the following may be quoted:

Plants grown with an abundant supply of available nitrogen and the opportunity for carbohydrate synthesis, are vigorously vegetative and unfruitful. Such plants are high in moisture, total nitrogen, nitrate nitrogen, and low in total dry matter, free-reducing substances, sucrose and polysaccharides.

Plants grown with an abundant supply of nitrogen and then transferred and grown with a very low supply of available nitrogen are very weakly vegetative and unfruitful. As compared with the vegetative plants, they are very much lower in moisture and total nitrogen and are lacking in nitrate nitrogen; they are much higher in total dry matter, free-reducing substances, sucrose, and polysaccharides.

Whatever the conditions under which a plant has been grown, considering the whole plant as a unit, increased total nitrogen and more particularly increased nitrate nitrogen are associated with increased moisture and decreased free-reducing substances, sucrose, polysaccharides, and total dry matter.

Fruitfulness is associated neither with highest nitrates nor highest carbohydrates but with a condition of balance between them.

Lack of fruit development is not alone due to the lack of pollination or fertilization. The flowers may fall soon after pollination (markedly vegetative plants) or remain attached for many days without development of the fruit (markedly non-vegetative plants).

Stems without storage starch at the base when cut off close to the surface of the soil, fail to sprout but decay quickly, whereas those with large storage produce new shoots. Accompanying such growth there is a total or complete disappearance of the starch, depending upon the relative amount of growth made and the available nitrogen supply. If the latter is abundant vegetative extension is relatively great; if not, such extension soon ceases and starch is again stored in the new growth.

The available carbohydrates or the possibility for their manufacture or supply, constitute as much of a limiting factor in growth as the available nitrogen and moisture supply. When the opportunity for carbohydrate manufacture within the plant itself is greatly reduced or eliminated even though there is a relative abundance of moisture and available nitrogen, vegetation is decreased. But when there is a carbohydrate reserve within the tissues under the same conditions of nitrogen and moisture supply, growth is active. Very large proportional reserves of carbohydrates to moisture and nitrate supply also accompany decreased vegetation.

Work (186) has studied the effect of measured applications of nitrate upon the performance and upon the nitrogen and carbohydrate content of tomato plants grown in quartz sand. Using boxes of about 1½ cubic feet capacity for single plants he found that 32 grams of nitrate of soda in a single application gave maximum results in both vegetation and fruitfulness. A given amount of nitrate in successive small portions was more effective than when applied in one application.

Treatments of over 32 grams per box did not result in rapid decline of plant activity. His data indicate that injury from heavy applications of nitrate is due to decrease in availability of soil moisture rather than to toxic action.

In his experiments he did not find it possible to induce a condition of heavy vegetation and unfruitfulness by means of large applications of nitrate of soda. Applications up to about 9 ounces per plant did not bring about such conditions, nor did one-third well-rotted manure, either when mixed with quartz sand or with soil. A nitrogen content of .3 to .4 per cent in the leaves was associated with vigorous vegetative growth and heavy fruiting; a content between .2 and .3 with intermediate performance, and less than .2 per cent with a check in both vegetation and reproduction.

He found no apparent relation between the amount of nitrate applied to the soil and the carbohydrate content of the plant, except where growth was checked by lack of available nitrogen. There was no apparent relation between nitrogen content and carbohydrate content except in starved plants, where the former was low and the latter usually high.

Among the conclusions given by Work the following may be of interest:

There is no indication that high or low carbohydrate content have inhibited either vegetative or reproductive activities of the plants in these experiments.

The concentration of carbohydrates in a plant is the resultant of the balance between the processes of manufacture and the many processes of use. The data of these experiments suggest that so long as the rate of manufacture is sufficient for current needs, the amount present does not condition the process of vegetation and fruition.

Kraus and Kraybill did not express their conclusions in terms of a mathematical ratio of carbon to nitrogen, but Crocker (33) did so interpret them. The results reported by Work do not support this interpretation, but suggest rather that nitrogen and carbohydrates be regarded as distinct limiting factors. Performance is to be related rather to the available amount of the single factor which is at the moment in minimo. From his results it appears that the carbohydrate requirement is amply provided for in any plant that has enough nitrogen for reasonable vegetative activity and that the stored surplus in nitrogen-starved plants is sufficient for renewal of growth.

Growing Plants.—The tomato crop is grown from plants started in a specially prepared seed bed several weeks prior to the time of planting in the garden or field. In most sections of the United States the seed is sown in greenhouses, hotbeds or cold frames. In the warmer sections of the South the plants are grown mainly under cloth-covered frames. In the colder sections of the South and in many regions of the North hotbeds are used for starting the plants. Greenhouses are employed to a considerable extent by market gardeners and others who grow tomatoes on a large scale in the northern states.

The time for sowing the seed depends upon the facilities available, the climatic conditions, and the purpose for which the crop is grown. If facilities are not available for transplanting the plants prior to setting in the field the seed should be sown only 4 to 6 weeks in advance of field planting. When left too long in the seed bed the plants usually get too "leggy" due to crowding. In regions having a short growing season the seed is usually sown 10 to 12 weeks before time for outdoor planting in order to have large plants. For a very early market crop, even in regions having a long growing season, early seed-sowing is practiced. Many growers sow the seed very early because they believe that slow growth is desirable, but experimental results indicate that this might be overdone. Werner (175) in North Dakota found that plants grown from seed sown February 27 produced less ripe fruit up to August 20 and less total yield than those grown from seed sown March 6, 16, 26 and April 6. Plants kept too long in the hotbed or greenhouse under ordinary methods of

growing either get too "leggy," or become too woody if the growth is checked sufficiently to hold them back. In either case the plants do not make a quick start when set out.

Tomato seed is usually planted in rows about 2 inches apart in flats, or in rows 4 to 6 inches apart in a hotbed, cold frame or greenhouse. If the plants are not to be transplanted prior to setting in the field they should be thinned to stand an inch or two apart preferably the latter distance, or even more when they are to remain in the seed bed for several weeks. Most market gardeners and other commercial growers in the North transplant the seedlings when they reach a height of about 2 inches, spacing them about 2 inches apart each way. The plants are often transplanted a second time when they begin to crowd, and, at this transplanting, they are spaced 3 by 3 or 4 by 4 inches apart each way, or else are put in flower pots, paper bands, veneer bands or tin cans. Experimental results indicate that transplanting is of no particular value if the plants are given the same space without transplanting. However, transplanting once is usually necessary to economize on greenhouse or hotbed space, but very often the second transplanting may be eliminated to the benefit of the plant and result in a saving of labor as well. (See Chapter VIII.)

Experiments indicate that plants grown from seed sown direct to pots or plant bands produce as large, or even larger yields than when transplanted once or twice.

Boyle (15) conducted experiments for 3 years in Indiana to determine the best and most profitable methods of growing tomato plants. The methods tested were as follows:

Plat 1. Seed sown in an outdoor seed bed in rows 18 inches apart and thinned to 2 inches apart in the row. These were taken from the seed bed to the field.

Plat 2. Seed sown in hotbed in rows 6 inches apart and thinned to 2 inches apart when one inch in height.

Plat 3. Seed sown in hotbeds in rows 6 inches apart and the seedling plants transplanted to flats when the first true leaves appeared.

Plat 4. The plants were handled exactly as for plat 3, except that they were transplanted twice into flats before going to the field.

Plat 5. Seed sown in 4-inch dirt bands, placed in a hotbed. Three or four seeds were sown in each band and later thinned to a single plant. The plant, soil and band were taken to the field and set.

The dates of seed sowing and setting in the field were the same for plats 2, 3, 4 and 5, but were later for plat 1. The seed for plat 1 was sown April 11, 1910, April 20, 1911 and April 20, 1912. Seed for plats 2, 3, and 4 was sown March 21, 25 and 23. The plant-band method of growing plants was not used in 1910. In 1911 and 1912 the dates of seed sowing was the same for plat 5 as for plats 2, 3, and 4. The yields, cost of growing plants and the value per acre are given in Table LII.

Table LII.—Results of Experiments in Different Methods of Growing Tomato Plants

(Adapted from Ind. *Bull.* 165)

Plat	Average yield tomatoes per acre, tons	Cost of growing plants per acre	Average value less cost of growing plants
1	5.26	$1.30	$ 51.30
2	10.15	4.90	96.60
3	10.30	4.95	98.05
4	10.82	6.70	101.50
5	14.92	8.80	140.40

A study of Table LII indicates an advantage from transplanting, but plants grown in flats have a decided advantage over those grown in the soil of the hotbed. Plants from the hotbed must be taken up and hauled to the field, while those grown in flats are not disturbed until they reach the field. The former probably lost some soil and also dried out to some extent. The difference in yield and value of the tomatoes from plats 2, 3, and 4 were very slight and were probably due to other factors than transplanting. While plat 5 was used for only two years and the comparison with the other methods is not quite as given in the table, yet the increase is so great that the value of the plant-band method of growing plants cannot be doubted. In fact if the results for 1911 and 1912 only are considered the comparison remains nearly the same.

Results similar to the above have been reported by Werner (175), Bailey (6), Munson (102), Bishop (12), Olney (110) and others. In all of the experiments the value of pots, or other receptacles has been shown. The main advantage of pots, plant bands, and tin cans over flats is mainly that the roots are not broken or disturbed when individual containers are used. When plants are grown in flats many of the roots are cut, or broken when removed for transplanting. The individual container usually has more soil per plant than the flat and this is also an advantage.

The plants should be hardened before they are taken to the field. This is usually done by subjecting them gradually to outdoor conditions, but withholding water serves practically the same purpose and may be followed where it is impracticable to use cold frames.

Setting Plants in the Field.—Since the tomato plant is tender it should not be set in the field until the danger of frost is past. In sections of Florida, where frosts seldom occur, plants are set in the fall and the crop is grown during the winter, but in practically all other sections of the United States they are planted in spring or early summer. For most regions early planting is important. In many sections of the South,

where the growing season is long, early planting is desirable because the plants die long before fall. In all sections of the North early planting is important because early fruit brings the highest price on the market, and, as a rule, the earlier the plants are set the larger the total yield, since the plants usually continue to bear and ripen fruit until killed by frost. App and Waller (1) in New Jersey found that the earlier the plants were set in the field, the larger the yield of tomatoes. In 1920 they secured records on 65 farms and the yields are given in Table LIII.

TABLE LIII.—YIELD OF TOMATOES ACCORDING TO DATE OF SETTING PLANTS (N. J. *Bull.* 353)

Date of planting	Number of farms	Number of acres	Yield per acre, tons
May 20 or before	16	236	6.65
May 20 to June 1	19	212½	5.75
June 1 to June 10	23	170½	5.54
June 10 or after	7	49	4.06

Data similar to the above were secured from over 300 farms in New York State in 1919 and 133 in 1920 and the results are more striking than those secured in New Jersey.

The space given tomato plants in the field depends upon the variety grown (large or small plant), soil used and the method of growing. On rich soils the distance apart should be greater than on medium or poor soils, and if the plants are pruned to one, or two stems the distance should be less than when they are allowed to grow on the ground without pruning. The usual distance for untrained plants is 4 by 4 feet on average soil. Other distances are 3 by 4, 3 feet 10 inches by 3 feet 10 inches, 4 by 5 or even 4 by 6 feet. As a rule more fruit is produced on a given area when the plants are fairly close together, than when they are set far apart. Yields from plants set 3 by 4 feet have been considerably larger than from those set 4 by 4 at Ithaca, New York. Plants trained to a single stem have produced a larger yield when set 2 by 3 than when set 2½ by 3 feet. Similar results have been reported by Rosa (126) in Missouri.

Plants are set by hand or with a machine transplanter. The machine is not satisfactory with large plants which have considerable soil around the roots, hence such plants are commonly set by hand. Large plants are usually set in a furrow made with a light plow. See Chapter IX for further details.

Cultivation.—Frequent, shallow cultivation is important until the vines interfere with the operation. After the vines get large enough

to cover most of the surface cultivation should cease, or be confined to the space between the rows, since it is not desirable to move the vines.

Experiments by Boyle (15) in Indiana show the importance of thorough cultivation. He compared average cultivation with what he called thorough cultivation for 3 years 1910, 1911 and 1912. In 1910, 15 cultivations and 8 hoeings resulted in a yield of 4.63 tons of tomatoes while with 4 cultivations the yield was 2.52. In 1911, 9 cultivations and 2 hoeings produced 13.78 tons while 3 cultivations and 1 hoeing produced 9.75 tons. In 1912 the yields were 13.36 tons for 8 cultivations and 1 hoeing, and 9.49 tons for 3 cultivations and one hoeing. The net profit from thorough cultivations was \$3.60 in 1910, \$35.80 in 1911 and \$34.70 in 1912. In these experiments the lower number of cultivations given each season represented the average for the region, while the larger number represented what was considered necessary to be called "thorough." App and Waller (1) show that the yield increased and the cost of production per ton decreased as the number of cultivations increased up to seven. Their records covered 3 years 1918, 1919, 1920 and the number of farms from which records were secured were 240, 205 and 205 respectively.

Pruning and Training.—The practice of pruning and training tomatoes is quite generally followed in the lower South and to some extent in other portions of the South. In the North it is practiced by a very small percentage of commercial gardeners and not at all by those growing for the canning factory. Various methods of pruning and training are practiced, the most common one being pruning to a single stem and tying the plant to a stake. Some growers prune to 2 stems while others prune to 3 stems. In the single-stem system all of the shoots which grow in the axils of the leaves are pinched out or cut out while they are still small. The plants are tied to stakes with soft twine, which is looped around the stake and tied under a leaf-stem on the side of the plant opposite the stake. The twine should not be tied around the plant in such a way that it restricts growth, or cuts into the stem. Usually the plants are trimmed about once every week or 10 days. Some growers pinch out the top of the plant when it reaches the top of the stake. With 2-stem, and 3-stem training the desired number of shoots are selected and all others are kept pinched out. Each stem must be tied as in the single-stem system.

The stakes are usually 1 by 1 inch or 1¼ by 1¼ inches square, or they may be made out of saplings cut from the woods in which case they should be about 1½ inches in diameter. They are usually 5 to 6 feet tall and are driven into the ground 12 to 18 inches deep and a few inches from the plant. Tomato plants are sometimes tied to wires attached to posts set in the ground or to heavy stakes driven into the soil to the proper

depth. Others support the vines on racks to hold them off of the ground. With this method the plants are trimmed very little, or not at all.

The advantages claimed for pruning and training are: (1) Earlier ripening, (2) larger fruits, (3) less disease injury, (4) larger yields, (5) cleaner fruit, (6) more convenient harvesting and (7) more convenient for spraying the plants. The disadvantages usually mentioned are: (1) Greater amount of labor and expense, (2) less total yield, (3) greater loss from blossom-end rot, (4) more sunscald on the fruit, (5) greater amount of cracking. It is also claimed by some authorities that pruning and training does not increase earliness.

In general growers and other authorities in the South favor pruning and training while those in the North do not favor the practice. However, some southern experimenters do not believe that pruning and training are profitable while some of the northern experimenters believe that they are. Whipple and Schermerhorn (176) report on results secured in Montana during 1906, 1911, 1912 and 1913. Ten to 12 varieties were included in the tests each year. In 1912 practically no ripe fruit was produced on either the pruned or unpruned plants, but in the other three years the pruned plants produced more ripe fruit than the unpruned plants. This was true for every variety. The pruned plants were pruned to a single stem and tied to stakes. The authors conclude that pruning and training are decidedly beneficial both from the standpoint of early ripening and quantity of fruit ripened. Wicks (182) in Idaho reports results from 3 years' experiments with various methods of pruning. The total average yield of marketable fruit per plat under the different treatments are given in Table LIV.

Table LIV.—Average Yield of Marketable Fruit per Plat for Three Years 1910 to 1912
(Idaho *Bull.* 76)

Plat	Treatment	Yield, lb. per plat
1	Pruned to 1 stem, on stake	744.39
2	Pruned to 2 stems, on stake	906.70
3	Pruned to 3 stems, on stake	948.12
4	No pruning, on stake	1,349.06
5	Pruned to 1 stem, on trellis	723.22
6	Pruned to 2 stems, on trellis	937.87
7	Pruned to 3 stems, on trellis	1,024.45
8	No pruning, on trellis	1,561.07
9	Pruned to 1 stem, on ground	700.96
10	Pruned to 2 stems, on ground	973.70
11	Pruned to 3 stems, on ground	912.63
12	No pruning, on ground	1,424.65

A glance at Table LIV shows that the largest yield of marketable tomatoes was produced on plants which were not pruned, but supported on a trellis and was followed by those neither pruned nor supported, and by those not pruned but supported by stakes. In general, the yield decreased in proportion to the severity of pruning. There was some advantage in earliness for the plants pruned to a single stem, but the largest yields of fancy tomatoes were produced on plats 8, 12 and 4 in the order given.

Lloyd and Brooks (89) have reported results of experiments in Illinois in which the yield was reduced in proportion to the severity of pruning. These experiments covered a period of 4 years in Union County and 3 years at Urbana. The treatments were as follows:

1. Pruned to single stem and topped.
2. Pruned to single stem and not topped.
3. Pruned to single stem early, then branched.
4. Pruned to two stems.
5. Pruned to three stems.
6. Staked but not pruned.
7. Neither staked nor pruned.

The results of the Illinois experiments are given in Table LV.

TABLE LV.—YIELDS OF TOTAL MARKETABLE AND EARLY MARKETABLE FRUIT PER PLANT IN ILLINOIS
(Ill. *Bull.* 144)

Treatment number	Yield marketable tomatoes, pounds per plant			
	Total yield		Yield early fruit	
	Union County	Urbana	Union County	Urbana
1	1.08	4.13	0.59	1.88
2	1.82	6.54	0.67	2.04
3	2.85	13.64	0.72	2.95
4	2.31	10.51	0.84	3.38
5	2.46	12.14	0.98	3.93
6	3.38	16.49	0.94	4.81
7	2.62	19.67	0.79	5.13

Table LV shows that in every instance the plants pruned to single stems produced low total yields and low yields of early fruit. In Union County the highest total yield was on plants unpruned and staked while at Urbana the highest yield was from plants neither pruned nor staked. Pruning had but slight effect on size of fruit and in only one case did the plants pruned to single stems produce the largest fruits. The authors state that pruning to single stem increased the injury from sunscald and cracking.

In the South pruning and staking has apparently increased the yields. Stuckey (155) carried on some experiments in Georgia in 1911 in which four methods of training were used. The methods used and the yields per plat of 104 plants were as follows:

	Pounds
1. Pruned to single stem	194.00
2. Pruned to two stems	257.10
3. Pruned to three stems	281.52
4. Neither pruned nor staked	140.30

It will be noted that the yield of plants tied to stakes decreased as the severity of pruning increased, but that all of the staked and pruned treatments produced higher yields than the plants which were neither pruned nor staked. All of the plants were planted the same distance apart, 4 by 4 feet. The length of the bearing season and the yield of fruit at the first picking were greater on the pruned and staked plants than on those neither pruned nor staked. The author comments as follows on the results:

However, pruning and staking cannot be recommended unreservedly. In 1908, as shown in *Bull.* 82 of this station, the unstaked plats yielded at the rate of 12,411 pounds per acre, while the staked plats yielded only 10,840 pounds per acre. In 1911 a staked and an unstaked plat in an area for the control of blossom-end rot also gave results in favor of the unstaked plat. The unstaked plat yielded for the first three harvests at the rate of 1,693 pounds per acre. For the same period, the stake plats yielded only 360 pounds per acre, practically the entire early crop on the staked plats being destroyed by the blossom-end rot. The season's yield from these plats was 3,441 pounds per acre from the unstaked and 2,202 pounds per acre from the staked plat.

Olney (110) secured favorable results from pruning and staking in Kentucky. In these experiments the unpruned plants were set 4 by 6 feet while the pruned and staked plants were set 2 by 4 feet apart in 2 years out of 3 and 2 by 3 feet in the other year.

The yield of marketable fruit per plant was less on the pruned plants than on those not pruned but the yield per acre was greater from the former, due to the much larger number of plants. As in the Georgia experiments, the blossom-end rot was greater on the pruned than on the unpruned plants.

Rosa (126) gives results of 4 years' work in Missouri in which the average yield in pounds per acre was 20,976 for plants set 2 by 3 feet staked and pruned to a single stem, 31,085 for plants set 2 by 3 feet staked but not pruned, 32,085 plants set 3 by 3 feet staked but not pruned and 39,840 for plants neither staked nor pruned. The author states that the highest percentage of early fruit was produced by plants staked and pruned to one stem, but the amount of early fruit was actually

greater from the plants allowed to grow in the natural way, and their yield of late fruit was much greater.

Results of the various experiments mentioned and others seem to justify the conclusion that pruning and staking in the North usually results in a reduced yield and a greatly increased cost. Blossom-end rot, sunscald and cracking are apparently increased by pruning and staking. There is practically no advantage in earliness nor size of fruit in favor of pruning and staking in the North. In the North pruning and staking largely has been discontinued because growers have found it unprofitable.

In the South, pruning and staking is quite generally practiced and experiments indicate that it might be profitable. It is probable that pruning is of more importance in the South than in the North, because of the greater severity of foliage diseases in the former region. Where foliage diseases are severe plants tied to stakes are usually less injured than those allowed to grow on the ground, due to the fact that the trained plants are more exposed to the sun and air than those not trained. This exposure allows the plants to become dry earlier in the morning and sooner after rains than is the case with plants not so exposed. During wet seasons pruned and staked plants show to much better advantage than they do during dry seasons and the reverse is true with unpruned and unstaked plants. The fact that blossom-end rot is nearly always severe during dry weather and is worse on trained than on untrained plants indicates that the pruning and staking either allows more moisture to escape from the surface of the soil or else the pruned plant cannot get the moisture as well as unpruned plants. Results of root studies made by the author (still unpublished) indicate that the latter is probably true. The root system of the pruned plants is reduced in about the same proportion as the top, hence it seems probable that pruned plants suffer more from drought than unpruned plants because the former cannot get as much of the available moisture as the latter.

Varieties.—A large number of varieties of tomatoes are in existence, but not as many as is indicated by the names found in the seed catalogs. In 1902 American seedsmen listed 327 so-called varieties, but undoubtedly many of the names were synonyms. Only a small percentage of the varieties grown in the United States at the present time are of much importance. Ten to 15 varieties constitute the bulk of the crop grown for home use, for market and for canning.

In choosing varieties of tomatoes the following points should be considered: (1) The purpose for which it is grown, whether for home use, for market, or for manufacture; (2) the length of the growing season; (3) yield and (4) susceptibility to disease. When the crop is grown for home use only the preference of the family should be considered as far as the quality, type and color of fruit are concerned. When grown for the

general market the preferences of the buyers must be considered. Some markets seem to prefer red-skinned fruits, while others prefer those with pink skin. Earliness is usually an important consideration in growing for the market, therefore, some early-ripening variety should be grown. For canning the following qualities are important: (1) High yield, (2) good color (bright red), (3) smooth surface, (4) small core and (5) fairly solid flesh.

The following are the most popular early varieties of a red color; Earliana, Bonny Best, Chalk's Jewel, and John Baer. The Earliana is the earliest of the four mentioned, but there are early strains of the other three which are as early as the late strains of the Earliana. Bonny Best, Chalk's Jewel and John Baer are so near alike that there are as great differences between strains of any one of these varieties as between the varieties.

June Pink is the earliest of the pink-skinned varieties. Globe, Early Detroit are medium-early, pink-skinned varieties. Beauty, an old variety, is still the most popular late, pink-skinned tomato. Acme is another old variety that is still grown. Ponderosa, a very large tomato with solid flesh is quite popular in the home garden.

Among the important medium and late, red varieties are Stone, Matchless, Perfection, Greater Baltimore, My Maryland and Red Rock.

In regions having a short growing season early varieties are grown for market and for canning because late-maturing varieties are usually killed by frosts before a profitable yield is produced. For canning in New York, Bonny Best, Chalk's Jewel and John Baer constitute at least 90 per cent of the crop. App and Waller (1) report that during the 3 years 1918–1920 Bonny Best, Greater Baltimore, Stone, Red Rock, Matchless, Trophy and Chalk's Jewel, in the order given, were the important canning varieties in New Jersey. These are the most important canning varieties in most sections of the United States, the early varieties being used where the growing season is short.

The following brief characterization of the important varieties is given merely as an aid in choosing varieties to meet certain requirements.

Earliana: An early variety producing only moderately vigorous vines with foliage quite susceptible to disease. Fruit red, often poorly colored at the stem end, inclined to crack, often rough, although strains of smooth-surfaced fruits are available. Losing in popularity but is still grown because it averages earlier than any other red variety. It is not a good shipping tomato.

Bonny Best: Averages a few days later than Earliana. Vines vigorous, prolific, foliage somewhat susceptible to disease. Fruit red, solid, medium in size, smooth, small core, and quite uniform in size and color. This is similar to Chalk's Jewel, but strains which resemble the original Bonny Best, as compared with Chalk's Jewel, produce a smaller

plant; the fruit is a trifle smaller, more symmetrical and not as flat, ripens a little earlier.

CHALK'S JEWEL: Vines vigorous; fruit medium to large in size, red and usually well-colored all over, smooth and regular. Ripens later than Earliana and averages a little later than Bonny Best.

JOHN BAER: A comparatively new variety similar to Chalk's Jewel and probably a selection of it.

JUNE PINK: An early variety, a few days later than Earliana, but the earliest of the well-known pink-skin sorts. Not as prolific as the Earliana.

GLOBE: A medium early variety, valued for its solid, globular fruit of a pink or purplish color. It is probably the most popular of the pink-skin sorts, and is largely grown in the South for shipping to northern markets.

STONE: This is one of the most popular of the late varieties used for canning. It is also a popular market variety in some regions. The plants are strong and vigorous, and produce a heavy yield of fruit where the growing season is long. The fruit is bright red in color of good size and smooth. This variety is too late for most sections of the North.

MATCHLESS: This variety is similar in every way to the Stone, but somewhat earlier.

GREATER BALTIMORE: This is a medium early variety. Plants are vigorous, and produce large yields; fruit large, smooth, somewhat globular in shape, firm, ripens evenly, bright red in color. This is a popular medium early variety grown extensively for canning.

MY MARYLAND: Plant medium size with a spreading, somewhat upright growth; fruit large, medium red color, somewhat flattened, firm and fine texture; the flesh is dark red, firm and sub-acid; core small. This variety resembles Stone, but is somewhat earlier and bears through a longer season. Not as reliable bearer as Stone.

PERFECTION: This variety was introduced by Livingston Seed Company of Columbus, Ohio, in 1880. It was selected from a field of Acme, which is a purple tomato, and is probably a result of accidental hybridization. The plant is large; fruit medium to large in size, somewhat flattened and of medium red color; core small; flesh light red in color, fine texture and firm.

BEAUTY: Plant large, spreading and somewhat upright; fruit large, somewhat flattened and slightly corrugated; purple-red color; flesh firm in texture; skin thick and does not crack badly. This is one of the most desirable of the pink- or purple-skinned sorts.

Diseases.—The tomato is subject to the attacks of a great many diseases affecting all parts of the plant, roots, stems, leaves and fruits Probably the most important diseases are fusarium wilt, bacterial wilt, leaf spot (leaf blight), early blight, late blight blossom-end rot and mosaic.

Fusarium Wilt (*Fusarium lycopersici*).—This disease is very widespread and is especially serious in the Middle Atlantic, Gulf coast and lower Mississippi Valley states. Wilt is characterized in its early stage by a wilting of the plant and an upward and inward rolling of the leaves. The leaves turn yellow and slowly die, the lower ones first but finally the upper ones also. A cross-section of an infected stem shows a dark-brown discoloration between the pith and bark. This discoloration of the woody layer distinguishes this disease from bacterial wilt.

Since the fungus causing wilt can live in the soil for several years control measures must consist of soil treatment, or the use of wilt-resistant strains or varieties. Soil treatment is not practicable except in the greenhouse where thorough sterilization will control the disease. Considerable progress has been made in developing wilt-resistant strains of tomatoes. Various wilt-resistant strains have been developed by various workers, the best known being Marvel, a selection from Marvel of the Market, a French variety; Arlington and Columbus, selections from Greater Baltimore; and Norton, a selection of Stone. According to Pritchard (119) these strains or varieties are not only resistant to the wilt but possess the other qualities desired.

Bacterial Wilt (*Bacillus solanacearum*).—Bacterial wilt or bacterial blight is often very serious in the South and is also present in many sections of the North, but usually not very destructive. Plants affected with this disease usually wilt more rapidly than those attacked by the Fusarium wilt. Affected plants remain green for awhile after they are infected then suddenly wilt. The discoloration of the stem is black rather then brown. When cut, the stem exudes a dirty, milky slime. The bacteria causing the blight can enter the plant only through a wound and are usually introduced by insects. They may also be carried from diseased to healthy plants by pruning knives and cultivating tools.

Sherbakoff (134) suggests the following control measures:

Make the seed bed on a soil not previously used for growing tomatoes or other crops susceptible to the disease, or sterilize the seed-bed soil with steam or formalin.

Rotate crops in the field so that tomatoes or crops related to them will not be planted on the same soil more often than once in several years. While this rule is generally a good one to follow, experienced tomato growers say its observance is imperative following a crop once affected with the blight.

The tomato field should be frequently inspected for blight and every diseased plant removed and destroyed.

Keep in check the various insects that may be working on the plants.

Do not plant tomatoes in a soil infested with root-knot nematodes.

Do not injure the plant roots unnecessarily in transplanting.

Leaf Spot (*Septoria lycopersici*).—Leaf spot or leaf blight is probably the worst disease of the tomato. The disease appears on the leaves as

water-soaked spots which finally turn brown. A yellowing of the leaf takes place and the edges begin to roll and the leaf finally dries up and drops off. The older leaves die first but the disease works outward or upward to new leaves until the plants are often almost completely defoliated before half of the crop is matured. Leaf spot is more serious during wet weather than in dry weather.

Control measures recommended are spraying plants in the seed bed every week or ten days, using 3–3–50 Bordeaux mixture; spraying plants in the field with 5–5–50 Bordeaux; rotation of crops, so that tomatoes are planted on the same land not more than once in 3 years and sterilize soil of seed bed or use new soil. While thorough spraying in the field will control the disease it has not been found practicable on a commercial scale.

Early Blight (*Alternaria solani*).—In many respects early blight is similar to leaf spot. The spots on the leaves are angular in outline and of a brownish or black color. Spots on the stems and petioles are dark, more or less circular, depressed areas. The fruit sometimes becomes spotted. The fungus causing this disease is the same that causes early blight of potatoes.

Spraying with Bordeaux mixture in the seed bed and in the field is recommended as a control measure.

Late Blight (*Phytopthora infestans*).—This disease is due to the same fungus causing late blight of potatoes. The disease appears comparatively late in the season and shows on the plants as black, water-soaked spots on the older leaves and stems. The spots enlarge and increase in number, killing the leaves and rotting the stem. In severe attacks the plant rapidly turns black and dies. On the fruit the spots are sunken and discolored, usually at the stem end.

Spraying with Bordeaux mixture has given good results in Virginia and elsewhere.

Blossom-end Rot.—This disease affects the fruit only and, as indicated by the name, it occurs at the blossom end. The first appearance is as a small yellowish spot around the dried-up blossom. The spot gradually enlarges and takes on a dark brown or black color. The affected tissue shrinks resulting in a more or less sunken spot. No causal organism has been found and authorities are agreed that it is a physiological disease due to certain conditions adverse to the normal growth of the plant. Irregular water supply, especially a sudden check in it is the chief cause of the disease. It nearly always appears in a dry season.

Any cultural practice which helps to conserve soil moisture aids in the control of blossom-end rot. Irrigation will completely control it, if properly used. Results secured by Stuckey (153) in Georgia seem to indicate that resistance and susceptibility to blossom-end rot are trans-

mitted from parent to progeny. Pruning and staking apparently increases the amount of blossom-end rot.

Mosaic.—Plants affected with mosaic show abnormal leaf development, variegated mottling of dark and light green areas predominating. At times diseased plants have fernlike leaves. In severe cases production is greatly reduced, but slightly affected plants often yield normal crops. This disease is often very serious on greenhouse tomatoes. Mosaic is highly infectious and spreads rapidly. Gardner and Kendrick (54) state that the same disease affects tobacco, pepper, petunia and a number of related plants including weeds:

> The disease is spread largely by insects, especially by plant lice, and certain cultural operations, such as pruning and transplanting.

Gardner and Kendrick (54) suggest the following control measures for mosaic:

1. Do not use tomato transplants from plant beds in which mosaic is present. Guard against spread during transplanting.
2. Eradicate all horse nettles, ground cherries in and near greenhouses, plant beds and tomato fields early in the season.
3. Keep tomato fields free of all solanaceous weeds, annual or perennial.
4. Keep plant beds free of all weeds and tomatoes during the summer.
5. Keep greenhouses free of volunteer tobacco and tomato plants and all related weeds.
6. Control insect carriers by spraying or fumigation.

Tomato Hornworms.—Tomato hornworms are large green worms, sometimes called tomato worms or tobacco worms as they feed about equally well on both plants. They are the larvae of large sphinx moths of two species which are similar in habits. The worms devour the foliage very rapidly. One worm will strip a large tomato plant.

Hand picking and spraying the plants with arsenate of lead are the control measures recommended.

Tomato Fruit Worm.—This worm is a very serious pest in many sections of the South, where it eats into the green fruit. It is the same insect as the boll worm of cotton and the corn earworm. Since it prefers sweet corn to tomatoes the latter may be protected by planting a row of sweet corn here and there in the tomato field. Spraying with arsenate of lead two or three times will partially control this worm.

Dropping of Blossoms.—Shedding of the blossoms frequently results in a low yield of tomatoes. Rolfs (124) states that during some years this trouble occasions a greater loss to the tomato growers (in Florida) than any diseases that are caused by micro-organisms. The blossoms develop and open, but drop off, leaving no fruit set. Blossom dropping may be caused by (1) a sudden occurence of cold or cool weather

at the time when the plants are in blossom, (2) hard rains, which may actually wash away the pollen, or otherwise affect pollination, (3) very hot dry weather, especially drying winds, (4) injury by thrips and (5) rapid vine growth due to excess of nitrogen.

Just how some of these factors affect fruit-setting is not definitely known. Unfavorable weather might seriously check the development of the pollen grains, prevent the opening of the anthers, injure the stigma, or, in some way interfere with fertilization. Thrips may cause the blossoms to drop due to injury to the delicate parts of the bud. On thrips-injury Watson (173) gives the following:

> The young, upon hatching, at once attack the tenderest part of the blossom or bud. The stamens seem to suffer first; but, as there is always much more pollen produced than can be used, no particular harm is done here. If there are only a few thrips present, say, one or two to each blossom, they usually find enough food in the stamens and do no harm to the crop. It is even possible that they are of service in cross-pollinating the blooms. But where there are a dozen of them in a single bloom, they attack other parts. Investigations in the tomato fields in the spring of 1912 showed as high as twenty thrips to a single bloom. When present in such numbers, various parts of the flower are attacked and seriously injured, especially the pistil. Soon after, the whole bloom turns yellow and falls off. If this is repeated for all the blossoms on the first three or four clusters which was often the case in that year, the crop is ruinously shortened, as these first fruits are the paying ones.

It is a matter of common observation that when tomatoes are grown in very rich soil, as in an old barn-yard, there is a very luxurious growth of vines provided the growing season is favorable. Very often little fruit is set on such vines, yet in a dry season vines growing under the same conditions produce a heavy crop of fruit. It has been assumed that excess of nitrogen, in some way, was responsible for the failure of the fruit to set. Many authorities merely state that vegetative growth is made at the expense of the fruit, but this does not explain the cause. Results of experiments conducted by Kraus and Kraybill (86) indicate that fruitfulness is associated with a condition of balance between nitrogen and carbohydrates in the plants. In their experiments those plants which were highly vegetative were high in moisture, total nitrogen, and nitrate nitrogen, and low in carbohydrates, and were unfruitful. Plants which were weakly vegetative were also unfruitful. These, as compared with the highly vegetative plants, were low in moisture, and total nitrogen and lacking in nitrate nitrogen, but were high in carbohydrates. Withholding water had the same effect on the plants as limiting the supply of available nitrogen.

Moisture in the form of rain, may, therefore, affect fruit-setting by making available to the plant the nitrate nitrogen in the soil. Moisture

in itself would not have this effect unless nitrate nitrogen were present in the soil. Hence a soil rich in organic nitrogen, even with ample moisture would not produce excessive growth of vine unless the conditions were favorable to the growth of organisms, which convert organic nitrogen into forms available to the plant. Even with a large amount of available nitrogen in the soil excessive vine growth would not be produced unless the moisture were abundant. This might account for plants setting a good crop of fruit one year and failing to do so another year, even with the same or similar soil.

Cost of Production.—The cost of production of tomatoes or any other crop varies greatly on different farms in any given region, and in different localities. These variations are due to differences in costs of labor, value of land, interest rates, cultural practices followed, and in practically all other items entering into the cost of production. As a rule the cost of growing tomatoes for the canning factory is less than the cost of growing for the general market. This is due largely to the fact that more intensive methods are followed in growing for market than for the canning factory. Norton (109) has published results of a survey on the cost of growing tomatoes on 133 farms in New York in 1920. Table LVI gives the average cost per acre of the various items, the total cost of growing, the total cost of harvesting, the receipts from tomatoes and the total cost per ton.

Table LVI.—Average Cost of Producing an Acre of Tomatoes on 133 New York Farms Growing 602.2 Acres in 1920
(Table 41 Cornell *Bull.* 412)

Item	Quantity per acre	Cost per acre	Per cent of total cost
Plants	3,377	$ 21.98	13.3
Fertilizer	602 lbs.	13.35	8.1
Manure charged to tomatoes	3 tons	6.23	3.8
Labor growing tomatoes:			
Human	62.0 hr.	26.19	15.9
Horse	61.1 hr.	14.98	9.1
Use of equipment	61.1 hr.	5.01	3.0
Use of tractor	0.7 hr.	1.31	0.8
Use of automobile and truck	....	0.46	0.3
Miscellaneous growing expenses	....	0.25	0.2
Interest on growing costs	....	2.03	1.2
Use of land	....	13.60	8.3
Total growing cost	....	$105.39	64.0

TABLE LVI.—AVERAGE COST OF PRODUCING AN ACRE OF TOMATOES ON 133 NEW YORK FARMS GROWING 602.2 ACRES IN 1920—*Continued*
(Table 41 Cornell *Bull.* 412)

Item	Quantity per acre	Cost per acre	Per cent of total cost
Labor harvesting tomatoes:			
Human	102.7 hr.	$ 42.58	25.9
Horse	37.4 hr.	9.15	5.6
Use of equipment	37.4 hr.	3.06	1.8
Use of automobile and truck	....	3.36	2.0
Miscellaneous harvesting expenses	....	0.59	0.4
Interest on harvesting costs	....	0.46	0.3
Total harvesting cost	....	$ 59.20	36.0
Total cost of crop	....	$164.59	100.0
Tomatoes disposed of other than to factory	0.08 ton	$ 2.47	
Tomatoes sold to factory	8.64 tons	183.17	
Total receipts from tomatoes	8.72 tons	$185.64	
Price received per ton	....	$ 21.29	
Cost per ton growing	....	$ 12.09	
Cost per ton harvesting	....	6.79	
Total cost per ton	....	$ 18.88	

App and Waller (1) have published results of a survey on the cost of production of tomatoes in New Jersey for a period of 3 years, 1918, 1919 and 1920. In 1918 records were secured on 280 farms, and in 1919 and 1920 the studies were made on 205 farms. The average cost of the various items, the average cost per acre and per ton are given in Table LVII.

TABLE LVII.—AVERAGE COST OF PRODUCING AN ACRE OF TOMATOES IN NEW JERSEY 1918, 1919 AND 1920

(Table 25 N. J. *Bull.* 353)

Items	1918		1919		1920		3-year average	
Number of farms	280.0*		205.0		205.0		690.0	
Acres grown	2,616.25		1,966.3		2,040.25		2,207.6	
	Amount	Cost	Amount	Cost	Amount	Cost	Amount	Cost
Seed, oz	2.176	$ 2.87	2.496	$ 0.60	2.4	$ 0.61	2.4	$ 1.50
Plants, no	893.0	....	1,320.0	3.63	1,338.0	3.26	1,173.14	2.08
Baskets, no	37.0	5.06	19.0	2.59	23.0	3.13	26.94	3.73
Cover crop, lb	29.0	0.99	50.4	1.68	28.2	1.04	35.4	1.21
Fertilizer, lb	801.0	14.62	891.0	20.08	859.0	18.71	884.42	17.50
Manure, tons	7.23	14.29	6.0	15.07	7.74	16.28	7.32	15.14
Lime, lb	174.0	0.20	700.0	1.60	480.0	0.66	420.0	0.76
Spray material	....	0.91	....	0.78	....	0.81	....	0.84
Man labor, hr	142.0	38.87	101.8	33.59	128.39	49.10	125.99	40.45
Horse labor, hr	100.0	20.00	69.5	16.38	80.68	16.33	85.03	17.80
Machine labor, hr	100.0	6.17	69.5	5.18	80.63	5.65	85.03	5.72
Truck labor, hr	2.93	4.13	2.2	3.22	3.48	5.21	2.86	4.20
Tractor labor, hr	0.08	0.12	0.2	0.31	0.65	0.98	0.30	0.44
Land rental	....	9.27	....	10.24	....	11.30	....	10.18
Interest on money, per cent	6.0	1.76	6.0	1.74	6.0	2.00	6.0	1.83
Miscellaneous†	....	....	....	1.72	....	0.53	....	0.69
Cost per acre	....	$119.26‡	....	$118.41	....	$135.62	....	$124.06
Cost per ton sold	....	19.13	....	56.56	....	23.64	....	25.58
Yield per acre sold	....	6.23	....	2.09	....	5.74	....	4.85
Yield grown per acre	....	6.83	....	2.09	....	6.07	....	5.19
Cost of harvesting, not including baskets	....	6.24	....	8.85	....	6.95	....	6.96

* Includes 40 Cape May County farms.

† Insurance, hot-bed materials, use of auto in getting plants, hauling hired.

‡ Omitting supervision charge of 10 per cent which was not made in 1919 and 1920.

Cost figures on tomatoes were obtained on 27 farms in Wood County, Ohio, by the College of Agriculture, Ohio State University. In this study the account method was used. The average cost per acre on 26 of these farms is given in Table LVIII. (Adapted from a mimeographed report by R. F. Taber as reported by Norton (109).)

Table LVIII.—Average Cost of Producing an Acre of Tomatoes on 26 Ohio Farms Growing 185.7 Acres in 1920

Item	Quantity per acre	Cost per acre
Plants	2,248	$ 8.99
Fertilizer	....	2.40
Manure charged to crop	2.3 tons	7.90
Labor growing tomatoes:		
Human	34.0 hr.	15.96
Horse	34.0 hr.	7.33
Use of equipment	34.0 hr.	2.38
Use of tractor	....	3.07
Interest and taxes on land	....	17.68
Interest on growing expenses	....	1.58
Total growing cost	....	$ 67.29
Total harvesting cost	....	$ 33.46
Total cost of crop	....	$100.75
Yield per acre delivered	6.4 tons	
Yield per acre including unharvested tomatoes	8.1 tons	
Cost per ton growing tomatoes delivered	....	$ 10.51
Cost per ton harvesting tomatoes delivered	....	5.23
Total cost per ton of tomatoes delivered	....	$ 15.74

An average of 7.1 acres of tomatoes per farm was grown on the Ohio farms. The average yield harvested per acre was lower than on the New York farms, and about the same proportion of the crop was not harvested. Very little fertilizer was used. The manure was charged at from $3 to $4 per ton.

The hours of human and horse labor were less than in New York. The costs given were for farmers keeping accounts on the crop, therefore they might be expected to be lower than for average farms. Also, the acreage of tomatoes per farm was fairly large.

In all of the studies reported there has been a great range in the cost per ton of tomatoes. According to Norton (109) 75 to 80 per cent of the total tonnage of the tomatoes produced on the 133 farms surveyed in New York in 1920 was produced at or below a cost of from $21 to $22 per ton. This tonnage was grown by 61 per cent of the producers on 64 per cent of the acreage. Table LIX shows the range in costs of producing tomatoes on 133 farms in New York in 1920.

TABLE LIX.—RANGE OF COSTS OF PRODUCING TOMATOES ON 133 FARMS IN 1920
(Table 58 Cornell *Bull.* 412)

Cost per ton	Number of farms	Per cent of total farms	Per cent of farms at this cost or lower	Acres	Per cent of total acres	Per cent of acres at this cost or lower	Tons	Per cent of total tons	Per cent of tons at this cost or lower	Yield per acre, tons
$10	3	2.3	2.3	17.0	2.8	2.8	319	6.1	6.1	18.8
11	4	3.0	5.3	16.6	2.8	5.6	241	4.6	10.7	14.5
12	1	0.7	6.0	2.5	0.4	6.0	234	0.6	11.3	13.6
13	8	6.0	12.0	40.0	6.6	12.6	415	7.9	19.2	10.4
14	10	7.5	19.5	39.0	6.5	19.1	457	8.7	27.9	11.7
15	9	6.8	26.3	46.8	7.8	26.9	544	10.4	38.3	11.6
16	5	3.8	30.1	17.8	3.0	29.8	241	4.6	42.9	13.5
17	11	8.3	38.3	70.0	11.6	41.5	680	13.0	55.9	9.7
18	12	9.0	47.4	37.8	6.3	47.7	348	6.6	62.5	9.2
19	7	5.3	52.6	48.5	8.1	55.8	394	7.5	70.0	8.1
20	6	4.5	57.1	25.5	4.2	60.0	202	3.8	73.8	7.9
21	5	3.8	60.9	23.5	3.9	63.9	193	3.7	77.5	8.2
22	6	4.5	65.4	25.0	4.2	68.1	174	3.3	80.8	7.0
23	7	5.3	70.7	37.7	6.3	74.3	265	5.1	85.9	7.0
24	6	4.5	75.2	20.5	3.4	77.7	168	3.2	89.1	8.2
25	4	3.0	78.2	14.5	2.4	80.2	97	1.8	90.9	6.7
26	2	1.5	79.7	12.0	2.0	82.1	64	1.2	92.2	5.3
27	2	1.5	81.2	4.0	0.7	82.8	23	0.4	92.6	5.8
28	1	0.7	82.0	2.0	0.3	83.1	13	0.2	92.9	6.5
29	3	2.3	84.2	15.0	2.5	85.6	65	1.2	94.1	4.3
30	2	1.5	85.7	7.0	1.2	86.8	32	0.6	94.7	4.6
31	1	0.7	86.5	3.0	0.5	87.3	14	0.3	95.0	4.7
32	3	2.3	88.7	6.5	1.1	88.4	35	0.7	95.6	5.4
33	1	0.7	89.5	6.0	1.0	89.4	31	0.6	96.2	5.2
34	3	2.3	91.7	7.2	1.2	90.6	41	0.8	97.0	5.7
35	2	1.5	93.2	9.0	1.5	92.1	46	0.9	97.9	5.1
38	1	0.7	94.0	2.3	0.4	92.4	9	0.2	98.1	3.9
40	2	1.5	95.5	23.5	3.9	96.3	55	1.0	99.1	2.3
41	1	0.7	96.2	5.0	0.8	97.2	15	0.3	99.4	3.0
45	1	0.7	97.0	3.0	0.5	97.7	14	0.3	99.7	4.7
47	1	0.7	97.7	2.0	0.3	98.0	5	0.1	99.8	2.5
60+	3	2.3	100.0	12.0	2.0	100.0	13	0.2	100.0	1.1
All farms	133	100.0	.....	602.2	100.0	.....	5,247	100.0		

The data in Table LIX show the relation of yield to cost per ton. In general where the yields were high the cost of production per ton was low and where the yields were low the cost was high. In a few instances, however, large yields were not produced at a low cost per ton. Over 20 per cent of the tomatoes grown on these farms in 1920 were grown at a loss. In general, where the yield was less than 7 tons to the acre the crop was produced at a loss and the average yield for a period of years in New York State is less than this.

Norton found that as the acreage of tomatoes per farm increased the yield also increased, due probably to better land and better methods of production. The man and horse hours per acre for growing the crop, and the cost of harvesting a ton, decreased as the acreage increased. He also

found that as the distance from the farm to the receiving point increased the charge per acre for use of land decreased, and the cost per ton for hauling increased.

Harvesting.—The stage of maturity at which tomatoes are picked depends upon the purpose for which they are grown and the distance they are to be transported. As a rule, tomatoes grown for a local market are not allowed to ripen as much before being picked as those grown for the cannery. This is due to the fact that market tomatoes may be on hand in stores two or three days before they reach the consumer, while cannery tomatoes are commonly put in the cans the day they reach the factory. In addition to this, tomatoes for canning must be red ripe in order to be of good color when canned.

The greater the distance from market the greener the fruit should be at the time of picking. Where tomatoes are to be in transit several days it is a common practice to pick them while they are still grass-green in color. This is true in most sections of the South where tomatoes are grown for distant markets. In Florida, until within the past few years, tomatoes were picked green and were sorted and packed immediately. Loss through disease and bruising was so great that it was found necessary to use a ripening house as a means of taking out unmarketable fruit before shipping. The fruit is held at a temperature of 75 to 85 degrees F. until a large percentage show a very slight red coloration. The fruits are then removed and carefully sorted; the colored ones are graded, wrapped and packed for shipment, while the green ones go back to the ripening room.

Sando (129) has the following to say regarding the use of the ripening room and the methods of handling the tomatoes in Florida:

The use of the ripening room is restricted to the early months of shipping, when the weather conditions are such as to allow the fruit to be shipped in a colored condition. The temperature is generally low enough to prevent too rapid ripening, and when the fruit reaches the North the temperature is still colder, thus allowing the fruit to be kept for a considerable length of time before it becomes too ripe. Later in the season, however, it is inadvisable with the present methods of handling to ship colored fruit. The tomatoes are kept in the ripening room for two or three days, to allow infections to develop, and are then sorted and shipped. In general, after warmer weather sets in the green fruit goes directly to the packing house from the field and is graded and shipped at once. Sometimes it ripens in transit, but more often it arrives green and has to be ripened at the terminal. Frequently the fruit is packed in such an immature state that it never attains its normal color. In such instances the grower loses both in reputation and in financial return.

When the tomatoes arrive at the packing shed they are dumped into bins, which usually are large enough to hold several crates. From these bins the grader culls all undesirable fruit and throws the good fruit into other bins, assorting according to size. Packers standing directly in front of the bins wrap the

fruits individually in special tomato paper and pack them in 4-quart baskets. Each basket requires smaller fruit at the bottom layer than at the top, where the basket is wider, but in every basket the fruit is packed very tightly; in some cases a little squeezing is necessary. Six baskets are placed in each crate. The top is considerably bulged, owing to the close packing of the baskets.

The method of packing crates for shipment just described is unfortunately the one generally used at the present time, but there is another method that deserves careful consideration, in which the fruit after it is picked is washed and handled by means of a machine.

The field crates used in connection with the machine, and also by many growers who do not use a machine, are made of hardwood mill edgings that have been carefully planed and smoothed, especially where the tomato is likely to come in contact with them. The crate is open, so that all sand and dirt fall through and do not injure the tomatoes during hauling.

When the tomatoes arrive at the packing shed they are dumped into a large tank at the end of the machine, which contains a special washing solution kept at as high a temperature as the fruit will stand. Were the solution with which the tomatoes are washed nothing more than hot water, it can hardly be doubted that the thorough removal of adhering sand, dirt and fungous spores would be beneficial. The tomatoes remain in this supposedly disinfectant solution for about half a minute, constantly revolving, and are pushed toward an endless chain which carries them up an incline where a spray of cold water rinses off the washing mixture. Drying is accomplished by passing the fruit between two layers of sponges. As it passes over the rollers, cullers are able to pick out the undesirable fruit without handling the remainder. It then passes over a special sizer, from which the several grades drop on tightly spread duck inclined planes and roll down into pockets. The tomatoes are not jarred or bruised in any way in traveling from the tank to the packer.

Careful handling is essential in the successful production and shipping of tomatoes, and machine handling in the packing house is therefore to be highly recommended. Any device which will prevent bruising and cutting will reduce the opportunities for fungous infection and subsequent loss.

Refrigerator cars without ice are preferred by the growers for shipping, since these cars are fitted with ventilators which can be opened and closed as weather conditions require. Ventilated cars are used also when there is a shortage of refrigerator cars, but owing to their poor construction there is likelihood in the colder regions of the fruit freezing. When the cars first leave the South the custom is to have the ventilators open, but as they move farther north these are closed to prevent frost injury. When the cars are billed through to Canada some shippers close the ventilators as soon as the cars are filled. Each car contains an average of 500 crates, or approximately 13 tons of fruit. With so large a volume of respiring fruit in a confined space it is obvious that a condition of oxygen deficiency may easily come about.

In most regions of the South the fruit is packed as soon as it is picked and, as it is usually very green, a great deal of the ripening takes place after it reaches the market. This requires extra sorting on the market and results in considerable loss.

Tomatoes picked green are selected on the basis of size alone and Sando (129) has shown that size is no criterion of maturity. He has also shown that fruit picked in this condition never develops the quality of vine-ripened fruits, or even of fruit picked after it has begun to turn pink. His analyses show that during development and maturation of the fruit there is an increase of moisture and a marked increase of sugars. Fruit, of the Livingston Globe variety, at 14 days of age contained 25.83 per cent sugars on dry-weight basis and at 56 days, when the fruit was turning, the sugar content was 46.03 per cent. When ripe the sugar content was 48.32 per cent. Starch decreased during maturation from 15.84 to 2.65 per cent, the most marked decrease occurring during the period of transition from green to red.

It is generally conceded that tomatoes shipped to northern markets from the South are inferior in flavor and palatability to vine-ripened fruit. Analyses of green, turning, and vine-ripened fruit reported by Sando (129) show that green fruit ripened at room temperature is lower in sugar and higher in acid than vine-ripened fruit. The ratio of sugar to acid was 5 : 54 in the artificially ripened fruit and 6 : 34 in the vine-ripened fruit. Tomatoes picked when they were turning ripened better than those that were picked green. The composition of turning tomatoes compared more favorably with vine-ripened fruit. The sugar-acid ratio was 6 : 78 in the former compared with 6 : 34 in the latter. Sando states that differences in the chemical composition between vine-ripened fruit and commercially picked green tomatoes, ripened in the laboratory, exposed to air and light, are not sufficient to account for the marked differences in flavor and palatability between commercially ripened fruit and normal fruit. He thought that lack of ventilation during commercial ripening might be responsible for the difference. He analyzed tomatoes which were ripened in a non-ventilated chamber and compared the results with those obtained with wrapped fruit. Comparisons were made between (1) tomatoes commercially picked and ripened without ventilation, (2) commercially picked and ripened, wrapped with one paper, (3) commercially picked and wrapped with three papers, (4) commercially picked and ripened unwrapped at room temperature, (5) picked when turning ripened unwrapped at room temperature, and (6) vine-ripened fruit. Commenting on the results of the analyses Sando (129) writes as follows:

There are striking differences in the analyses between the acid and carbohydrate content of tomatoes commercially picked and ripened without ventilation and the same fruit ripened when exposed to the air. Without ventilation the acids are very high and the soluble carbohydrates (sugars) are low. These facts indicate incomplete oxidation of carbohydrates to carbon dioxid (CO_2) with the consequent accumulation of acid. The connection of these changes in composition with the flavor is very obvious. The nonventilated fruit was

markedly inferior. Although the reaction was decidedly acid, the general flavor was insipid. While the same effect was not produced to as great an extent in fruit ripened when wrapped with paper, it nevertheless takes place. Fruit wrapped with one paper had a noticeably inferior flavor; it was not as poor as the sample ripened without ventilation, but it was worse than that of green fruit ripened without wrapping. The acid content of fruit ripened without ventilation shows an increase of approximately 138 per cent over that of vine-ripened fruit; that of fruit ripened while wrapped with one paper, an increase of approximately 102 per cent; and that of fruit ripened while wrapped with three papers, an increase of about 58 per cent. The soluble carbohydrate content for fruit ripened without ventilation shows a decrease of nearly 21 per cent compared with normal fruit; that of fruit ripened while wrapped with one paper, a decrease of nearly 5 per cent; and that of fruit ripened while wrapped with three papers, a decrease of nearly 6 per cent.

Tomatoes grown for nearby markets should be picked while they are still solid but should be well colored, so that sorting in the store will not be necessary. Sorting injures the fruits and is likely to increase decay as well as add to the cost of handling.

At the time of picking it is desirable to remove the stems since they are likely to injure the fruits during handling.

Grading.—Before tomatoes are packed they should be thoroughly graded to pick out all inferior specimens and to separate them into grades based on size, stage of ripeness and other factors. The U. S. Bureau of Markets suggest three grades: U. S. Grade No. 1, U. S. Grade No. 2, and U. S. Grade No. 3. The specifications for these grades are as follows:

U. S. No. 1 shall consist of tomatoes of similar varietal characteristics which are mature but not overripe or soft; well formed, fairly smooth, which are free from damage caused by sunscald, catfaces, growth cracks, freezing, disease, insects, hail, scars, or mechanical or other means.

In order to allow for variations incident to proper grading and handling, not more than 10 per cent, by count, of any lot may be below the requirements of this grade but not to exceed one-half of this tolerance shall be allowed for any one defect.

U. S. No. 2 shall consist of tomatoes which are mature but not overripe or soft, which are free from serious damage caused by sunscald, catfaces, growth cracks, freezing, disease, insects, hail, scars, or mechanical or other means and from any defect or injury that has penetrated through the fleshy outer wall of the tomato.

In order to allow for variations incident to proper grading and handling, not more than 10 per cent, by count, may be below the requirements of this grade but not to exceed one-half of this tolerance shall be allowed for any one defect.

U. S. No. 3 shall consist of tomatoes which do not meet the requirements of any of the foregoing grades.

The following marking requirments for size and definitions of terms are also given:

The minimum size, numerical count, or description of pack of the tomatoes in any package shall be plainly labeled, stenciled or otherwise marked on the package.

"Minimum size" means the greatest diameter of the smallest fruit measured at right angles to a line running from the stem to the blossom end. It shall be stated in terms of whole and quarter inches as 2 inches minimum, 2¼ inches minimum, 2½ inches minimum, and so on in accordance with the facts. In order to allow for variations incident to proper sizing, not more than 10 per cent, by count, of the tomatoes in any package may be below the minimum size specified.

"Description of pack" applies particularly to California conditions and shall be designated according to the arrangements of the tomatoes in the top layer in a lug as 5–5, 5–6, 6–6, and so on in accordance with the facts. The figures given represent the numbers of rows of tomatoes each way in the lug and it is understood that the two bottom layers of tomatoes in any lug shall not contain more than one additional row each way, *i.e.*, that in a 5–5 pack the tomatoes in the two bottom layers must not be smaller than will pack 6 rows each way as 6–6.

"Similar varietal characteristics" means that the tomatoes shall be alike as to firmness of flesh and shade of color, *i.e.*, that soft-fleshed early-maturing varieties shall not be mixed with firm-fleshed mid-season and late varieties or bright red varieties mixed with varieties having a purplish tinge.

"Mature" means that the contents of the seed cavities have begun to develop a jelly- or glue-like consistency and the seeds are fully developed.

"Well formed" means the normal, typical shape for the variety.

"Fairly smooth" means not noticeably ridged, angular, indented or otherwise misshapen.

"Free from damage" means that the tomatoes shall not be injured to an extent readily apparent upon examination.

"Catfaces" mean irregular, dark, leathery scars usually found at the blossom end, but sometimes on the sides. If shallow and no greater in total area than a dime they shall be allowed in U. S. No. 1.

"Growth cracks" are ruptures or cracks radiating from the stem end. If well healed over and not longer than ½ inch they shall be allowed in U. S. No. 1.

"Serious damage" means surface blemishes covering more than 15 per cent of the surface in the aggregate or any deformity so serious as to cause a loss of over 20 per cent in the ordinary process for preparation for use.

Packing.—The methods of packing tomatoes and the types of package used depend largely on the market preference and the distance they are shipped. For nearby markets tomatoes are usually packed in open containers, mainly 16-quart hampers, round stave baskets holding 3 or 4 pecks, splint baskets holding 10 to 16 quarts, boxes and crates of various kinds. For long-distance shipping the tomatoes are commonly packed in flat peach baskets which are placed in carriers holding 4 or 6 baskets. The baskets commonly used in these carriers have a capacity of 4 quarts. The tomatoes should be carefully placed by hand in the containers and packed tightly so there will be no shifting of the fruits.

Relatively small, flat packages are desirable for tomatoes since they are heavy and quite soft, and are likely to be crushed in the bottom of a tall package, such as the ordinary hampers, or even the round stave basket. The package should be substantially built so that it does not give when lifted. The 4- and 6-basket carriers are probably the best packages now used for shipping tomatoes long distances.

While tomatoes grown in the South are usually wrapped before being packed results secured by Sando (129) indicate that the practice should be discontinued. The wrapper prevents proper ripening, delays cooling, interferes with quick and thorough inspection, favors the development of disease by holding moisture. It also adds to the expense.

EGGPLANT

The eggplant, also called Guinea squash in the South, is grown for market mainly in the warmer sections of the United States. It is grown commercially to some extent as far north as Long Island, and in other regions having similar climates. In regions having a short growing season and a cool climate, they are seldom grown except for home use, since satisfactory crops cannot be produced under such conditions.

The eggplant is of relatively minor importance commercially. In 1919 the value of the crop grown for sale was $491,321, as reported by the Bureau of the Census. This was produced on 1,712 acres and the value per acre was $287. Nearly three-fourths of the crop was produced in two states, New Jersey with 702 acres valued at $165,131 and Florida with 562 acres valued at $203,445.

History and Taxonomy.—The eggplant is probably a native of India and has been in cultivation for a long time. Some authorities claim that the eggplant can be recognized from description published as early as the fifth century. It probably was not known in Europe at the time of the ancients.

It belongs to the Solanaceae or nightshade family and is known under the botanical name *Solanum melongena*. Most all of the cultivated varieties belong to botanical varieties of the species mentioned. The common eggplant, to which the large-fruited forms, such as New York Improved, belong, is known under the name *S. melongena* var. *esculentum*. The plant is bushy and grows to a height of 2 to 4 feet; the leaves are large and alternate on the stems; the flowers are large, violet colored and are borne singly, opposite the leaves. The serpentine or snake eggplants are placed under the variety *serpentinum*. The fruit of this group are long and slender, one inch or less in diameter and 12 to 15 inches long. The dwarf eggplants are known under the variety name *depressum*. These produce small, weak, spreading plants, nearly smooth. The leaves are small and thin, and the flowers are much smaller than those of the common eggplant. The fruits are small, pear-shaped, and purple in

color. The dwarf forms do not require as long to mature as the common form and are better adapted to regions having a short growing season.

Culture.—The cultural requirements of the eggplant are practically the same as for the tomato except that it requires a longer growing season and is more seriously checked in growth by cool weather. To grow the crop successfully the plants must not be checked in growth. Seeds are sown in a greenhouse or hotbed 8 to 10 weeks prior to the time the plants are to be set in the field or garden. The plants are always transplanted at least once before they are set outdoors and pots, plant bands, or other individual containers are often used so that there will be as little check in growth as possible when they are planted in the field. The eggplant is a hot-season crop, therefore, the plants should not be set out until all danger of frost is over and the weather has become warm.

The plants are set 2 to 3 feet apart in rows 3 to 4 feet apart. For the large growing varieties 3 by 4 feet is none too far apart.

Warm, sand, or sandy loam, well-drained soils should be selected, especially in the North. The soil should be rich. Heavy fertilizing is usually practiced. Manure is very often used and this is supplemented with 500 to 1,000 pounds of a high-grade, commercial fertilizer with part of the nitrogen in a readily available form.

Cultivation given the eggplant is practically the same as that given the tomato.

Varieties.—Relatively few varieties of eggplants are offered by American seedsmen. Three distinct colors, black, purple and white are grown but the black-fruited varieties are the most popular. White-fruited varieties are seldom found on the market. Purple-fruited sorts are attractive, but the smaller size of the fruit is objectionable from the market standpoint.

The most popular varieties are New York Improved and Black Beauty. Other varieties listed by seedsmen are Black Pekin, Early Long Purple, the hardiest of all varieties and adapted to the cooler parts of the North, and Ivory. The last named variety is a white-fruited sort originated by Dr. Halstead of the New Jersey Experiment Station.

Wilt (*Verticillium alboatrum*).—This disease causes a yellowing and wilting of the foliage and gradual defoliation. Affected plants make a stunted growth, and many die prematurely. In the later stages the wood of affected plants shows a dark discoloration.

Crop rotation is recommended as a control measure.

Bacterial Wilt (*Bacillus solanacearum*).—This disease is caused by the same organism responsible for the bacterial wilt of the tomato.

Fruit-rot (Leaf Spot, Stem Blight) (*Phomopsis vexans*).—This is a serious fungous disease which attacks all parts of the plant above ground. The spots on the leaves are brown, circular or oblong, becoming irregular with age. The centers of the spots become grayish and the

margins almost black. Spots on the fruit start with grayish or light brown blotches which develop into a soft rot, frequently covering the entire fruit. The disease on the stem is most common on the seedlings where it causes a damping off.

Disinfection of the seed by soaking for 10 minutes in corrosive sublimate solution 1 to 1,000, use of clean soil in the seed bed and rotation of crops are control measures recommended. In treating seed it is important to rinse the seed in running water for fifteen minutes after soaking in corrosive sublimate.

Eggplant Flea-beetle (*Epitrix fuscula*).—This small black flea-beetle is a very serious pest of the eggplant. It is especially injurious while the plants are small.

Dipping plants in 3–3–50 Bordeaux mixture at the time of transplanting and spraying 10 days to 2 weeks later with 4–4–50 Bordeaux, to which has been added 4 pounds of arsenate of lead paste to each 50 gallons, will usually keep this insect under control.

Colorado Potato Beetle.—This insect is often very injurious to eggplant. (See discussion under potato, Chapter XXIII.)

Eggplant Lace-bug (*Gargraphia solani*).—The lace bug injures the plant by sucking the juices. This insect is a small lace-bug, about $\frac{1}{6}$ of an inch long.

Spraying with whale oil soap, 8 pounds to 50 gallons of water, or with nicotine sulphate, 8 ounces to 50 gallons of water will aid in keeping this insect under control.

Eggplant Tortoise Beetle (*Cassida pallidula*).—This insect is quite widely distributed over the more southern portions of the United States, and has been reported from some of the northern states. Both the larva and adult injure the plant by eating holes in the leaves, and while they seldom cause great injury, at times they are quite destructive. This insect feeds on the Irish potato and some of the wild species of Solanum. Jones (80) found that the larvae could be kept under control by spraying with arsenate of lead, 1 pound of powder to 50 gallons of water and with arsenite of zinc, powdered, at the rate of 1 pound to 50 gallons of water. He recommends dipping the plants in some spray mixture at the time of field planting.

Harvesting.—The fruits of the eggplant are edible from the time they are one-third grown until they are ripe. They remain in an edible condition for some time after they become fully grown and colored. A heavier crop will be produced if the fruits are removed before they reach full size, but they should be well colored and of good size in order to sell well on the market.

The fruits are usually cut from the vines since the stems are hard and woody. The large calyx and a short piece of the stem is left on the fruit, but care should be taken to prevent the stem injuring other fruits

in the package. They are heavy and should be handled with care even though they are not as perishable as the tomato. The fruits are sometimes put in paper bags, one fruit to each bag, or wrapped in paper, before being packed for shipping. They are often packed in berry crates of 32 to 60 quarts capacity although other substantial crates are used as shipping packages. Before packing they are usually graded somewhat to separate the sizes and to cull out inferior fruits, but no definite grades are recognized.

PEPPER

The pepper belongs to the genus *Capsicum* and is very distinct from the pepper of commerce, which is the fruit of *Piper nigrum*, belonging to another family. Peppers are used in a great variety of ways. Cayenne pepper or red pepper of commerce consists of fruit of small pungent varieties ground to a fine powder. Pepper sauce of various kinds consists of the fruit of pungent varieties preserved in brine or strong vinegar. Tabasco sauce is said to be the juice of pungent varieties, expressed by pressure. Paprika, a Hungarian condiment, is made from fruit ground after the seeds have been removed. Peppers are used in pickles of various kinds and the sweet varieties are sliced and eaten as a salad. They are used in stuffing pitted olives, and the large sweet varieties are stuffed and baked. A small-fruited variety of peppers is used for decorative purposes.

Peppers have very much the same cultural requirements as the eggplant, although the plants will withstand lower temperatures. They thrive best, however, in a warm climate and a long growing season. They are grown to a very limited extent in the eastern portion of the United States farther north than New Jersey.

The important states which produce green peppers for market are New Jersey, California and Florida. These three states produced about 80 per cent of the crop grown for sale in the United States in 1919. New Jersey was in the lead with 5,416 acres valued at $883,654 and was followed by California with 4,870 acres valued at $753,740 and Florida 2,002 acres valued at $801,111. The country, as a whole, produced 15,290 acres valued at $3,079,285 with an average value per acre of $201. The value per acre in Florida was $400, in New Jersey $163 and in California $155. The high value in Florida is due to the fact that peppers are grown there for shipping to the northern markets during the winter and spring when there is no competition and prices are high.

History and Taxonomy.—Peppers probably had their origin in tropical America, though numerous so-called species have been attributed to southern Asia. They were not known in Europe prior to the discovery of America and DeCandolle (Origin of Cultivated Plants) stated that no ancient Sanskrit or Chinese name is known for the genus and neither

were the Greeks, Romans nor even Hebrews acquainted with it. It was first mentioned by Peter Martyn in an epistle dated September 1493 in which he says Columbus brought home "pepper more pungent than that from Caucasus" (Sturtevant Am. Nat. 24; 151.1890). Peppers were disseminated rapidly in Europe after the discovery of America. Three varieties were figured in 1542, thirteen in 1611, twenty in 1640 and thirty-five in 1699. Linnaeus recorded two species in the first edition of Species Plantarum 1753 and three additional species were added by 1797. Oviedo (1514) mentioned the use of peppers in tropical America.

Peppers belong to the Solanaceae family and the genus Capsicum. While early botanists recognized many species Irish (76), after a very thorough study of the genus, recognized only two, *C. annuum* and *C. frutescens.* The former furnishes all the leading commercial varieties now in cultivation. In tropical countries *C. annuum* is a biennial or perennial, while in temperate latitudes it is grown as an annual. Irish recognized the following botanical varieties of *C. annuum.*

Var. *conoides:* Fruit oblong, linear; calyx usually embracing the base of fruit. Fruit usually less than 1½ inches long; peduncles about as long or longer. Tabasco, Cayenne and Orange Red Cluster belong here.

Var. *fasciculatum:* Fruit usually more than 1½ inches long; peduncles shorter, leaves and fruit fascicled; fruit erect. Yellow Cluster and Red Cluster belong to this group.

Var. *acuminatum* (Fingerhut): Leaves and fruit not fascicled. Long Cayenne and Chilli belong here.

Var. *Longum* (Sendt): Calyx not embracing base of fruit except in the Ivory Tusk Variety. Long Red, Long Yellow, Black Nubian and Ivory Tusk belong in this group.

Var. *grossum:* Fruit oblate or oblong, truncated, deeply lobed furrowed and wrinkled; flesh mild, 1/12 to 1/8 inch thick. Bell, Bullnose, Ruby King, Sweet Mountain and other large sweet peppers belong in this group.

Var. *abbreviatum* (Fingerhut): Fruit subconical, ovate or elliptical, slightly longer than broad, 3/4 inch to 2 inches long. Calyx not embracing the base.

Var. *cerasiforme:* Fruit generally smooth, oval, spherical, cherry or heart shaped 3/8 inch to 1½ inches in diameter, calyx seated on the base. Cherry Pepper.

Culture.—Peppers are grown in very much the same way as eggplants and tomatoes. The plants are started in greenhouses or hotbeds in most regions and are handled in the same manner as tomatoes. They are set out after all danger of frost is over and the weather is warm. The spacing of the plants is less than for either eggplants or tomatoes. Rows 2½ to 3 feet apart with the plants about 18 inches apart are the common distances. Pepper plants require continuous growth for satisfactory

results. It requires at least three months' growing season to produce a profitable yield and a longer period is desirable:

Varieties.—Two classes of peppers are grown, those which produce pungent or "hot" fruits and those which bear mild or sweet fruits, the latter being known as "sweet peppers." The most popular varieties of the pungent-fruited peppers are Tabasco, Long Red Cayenne, Red Chilli, Red Cluster, Birdseye or Creole and Cherry. Of the large-fruited, sweet peppers, Ruby King, Bell or Bullnose, Chinese Giant, Sweet Mountain, Neapolitan and Golden Queen, are well-known varieties. These are popular for serving as "stuffed peppers" and for use in salads.

Pimiento or Spanish Pepper is a mild, thick-fleshed type, which has become popular in the United States during recent years. It is grown to a considerable extent in the South and is popular for canning. The term "pimento" is often used but the Spanish term "pimento" is applied to Allspice, a species of aromatic trees. Pimiento peppers are usually smoother and more pointed, have thicker flesh and are heavier than Bell peppers. According to Stuckey and McClintock (156) an average bushel of ripe Spanish peppers weighs 33 pounds:

Of this amount 22.68 pounds are pulp or fleshy part used for canning, 5.15 pounds are cores, 2.06 pounds are stems and 3.09 pounds are seeds.

In a bushel of ripe Bell peppers there are 22 pounds of pulp, 3¼ pounds of cores, ½ pound of stems and ⅞ pound of seed.

Perfection is the best known variety of pimiento or Spanish pepper.

Diseases.—Peppers are subject to several diseases, including Anthracnose or rot (*Colletotrichum nigrum*), leaf spot (*Cercospora capsici* and mosaic, but usually they are not very serious. Anthracnose is a common fruit rot which sometimes causes considerable loss. Cook (27) states that it is most severe on sunburnt fruit and while little effort is made to control it the most satisfactory treatment is Bordeaux mixture. Mosaic of pepper is the same as the mosaic of tomato. Leaf-spot appears on the leaves as grayish-brown spots. Seriously affected leaves wilt and fall off. Disinfecting the seed with corrosive sublimate, 1 to 1,000 for 10 minutes, use of disease-free soil for the seed bed, and spraying the plants with Bordeaux mixture while still in the bed are control measures recommended. In seed-disinfection it is important to rinse the seed for 15 minutes in running water after soaking it in corrosive sublimate.

Insects.—The pepper plant is seldom injured to any great extent by insects although it is sometimes attacked by the potato aphis, flea-beetle; potato beetle and spinach aphis.

Harvesting.—The stage of maturity at which peppers are picked depends upon the purpose for which they are grown and the demand on the market. The large sweet peppers are usually picked while still green

in color when they are sold on the general market, although there is some demand for red ones. Canners demand a bright red color.

The fruits will remain on the plants for some time after reaching maturity without deterioration. They are usually picked by snapping off the brittle stems with the hand.

Peppers are packed for market in various kinds of containers including the half-bushel, bushel and half-barrel hamper, bushel stave basket, and to some extent, in 4- and 6-basket carriers.

HUSK TOMATO

The husk tomato (*Physalis pubescens*) is cultivated to some extent in the gardens of the United States, but it is not grown commercially. The plants are decumbent and produce a small, round fruit of a yellow color inside of a thin husk. There are several native species of Physalis known as "ground cherry." The fruits of the husk tomato are sometimes used for preserves. They may be eaten raw, but they are rather insipid in flavor.

The plants are easily grown and are handled in the same manner as tomato plants. In general the cultural requirements of the husk tomato are the same as for the tomato.

CHAPTER XXVI

THE CURCURBITS OR VINE CROPS

Cucumber	Watermelon
Muskmelon	Pumpkin and Squash

The cucurbits or vine crops are tender annuals grown for their fruits. These crops thrive only in hot weather and will not withstand frost. All of these crops belong to the same family, Cucurbitaceae, and all have similar cultural requirements as well as many of the same disease and insect pests. From every point of view they should be grouped together for discussion. All of the plants in this group are monoecious (the stamens and pistils being in separate flowers on the same plant).

CUCUMBER

The cucumber is an important vegetable crop, being grown in the home garden, in market gardens, on truck farms in the South for shipping to northern markets, as a forcing crop and as a special crop for the pickle factories in various parts of the United States. The cucumber is not important from the standpoint of its food value, but it is widely used in salads and in mixed pickles.

Statistics of Production.—In 1919 the value of the cucumbers grown for sale in the United States was $8,579,102. The area of land devoted to this crop was 51,643 acres and the value was $166 per acre. Table LX shows the acreage, total value and value per acre, of the crop in the important states for the year 1919.

Table LX.—Acreage, Total Value and Value per Acre of Cucumbers Grown in 1919

(U. S. Census figures)

State	Acres harvested	Value of product	Value per acre
Michigan	10,351	$1,176,686	$114
New York	4,840	821,621	170
Wisconsin	4,631	588,543	127
Florida	4,549	1,389,665	305
Illinois	2,418	451,608	187
New Jersey	1,995	233,475	117
Ohio	1,989	382,950	193
Pennsylvania	1,925	391,239	203
California	1,786	313,432	175
Indiana	1,685	218,033	129
Colorado	1,589	238,392	150

A glance at the table shows that Michigan produced nearly one-fifth of the entire acreage of cucumbers grown in the United States. Four states, Michigan, New York, Wisconsin and Florida produced about one-half of the crop. In most of the important producing states, except Florida the crop is grown largely for pickles. Other states producing over 1,000 acres in 1919 are South Carolina, Maryland, Massachusetts, Virginia and Texas.

History and Taxonomy.—The cucumber is probably a native of Asia and Africa and has been in cultivation for thousands of years. There is evidence that its culture in western Asia dates back at least 3,000 years and it is said that the cucumber was introduced into China from the west 140 to 86 B. C. It was known to the ancient Greeks and Romans and Pliny even mentions their forced culture (Sturtevant). The cucumber was known in France in the ninth century and was common in England in 1327. It was grown by the early colonists in America and is said to have been grown by the Indians in Florida in 1539.

The cucumber belongs to the genus Cucumis of which there are 20 to 25 species found mostly in Asia and Africa, only two, *C. sativus* and *C. Melo* being of much importance in the United States. A third species, *C. Anguria*, West Indian Gherkin, is found in the South and tropical America. The cucumber is a trailing or climbing plant with hairy, angular stems and large leaves with long petioles. The flowers are axillary, the staminate being more numerous than the pistillate.

Soil Preferences.—Cucumbers can be grown on almost any type of soil. Where earliness is a prime consideration a sandy or a sandy loam is selected for cucumbers, but where heavy yields are most important a good loam or clay loam is preferred. On the heavier soils the yields are usually larger and the bearing period longer than that on light soils. The soil should be well drained, but retentive of moisture, especially for a late crop. In the South where cucumbers are grown during the winter and spring, for shipping to northern markets, a sandy loam soil is usually selected.

Manures and Fertilizers.—Stable manure is valuable for cucumbers but it is not essential where humus is furnished by turning under green-manure crops, and the principal fertilizing elements are supplied in the form of commercial fertilizers. Experimental results reported by Thorne (163) indicate that on a gravelly, alluvial soil in southeastern Ohio green-manure crops and commercial fertilizer give practically as good results as manure. An application of 400 pounds of acid phosphate, 50 pounds of nitrate of soda and 160 pounds of muriate of potash produced slightly larger yields than 16 tons of manure alone. In these experiments the crop responded more to phosphorus than to nitrogen or potash. All of the plats in these experiments produced a green-manure crop each year. The results are shown in Chapter III.

Where manure is used in small quantities it is desirable to apply it in the row, especially if it is well-rotted. After it is placed in the trench the soil should be thrown back over it and the seed planted over the manure. If manure is used in large quantities it is best to apply it broadcast. Even where manure is used some commercial fertilizer should be applied. On a fairly productive soil 400 pounds of acid phosphate and 100 to 150 pounds of nitrate of soda in conjunction with manure should be sufficient. When manure is not used some green-manure crop should be turned under to supply humus, and 500 to 1,500 pounds of fertilizer applied. On poor soils 1,000 to 1,500 pounds of a mixture containing 2 to 4 per cent nitrogen, 8 to 10 per cent phosphoric acid and 5 to 6 per cent potash is recommended. On rich soils 400 to 500 pounds of acid phosphate and a little nitrate of soda to give the plants a start, should produce good yields.

Planting.—Since the plant is very tender, and the seeds will not germinate in a cold soil planting should be delayed until all danger of frost is over and the ground is warm. Market gardeners often take chances on an early planting since earliness is an important factor. Some growers plant seed at two different depths at the same time, the shallow planting coming on first, and if these plants are killed by frost the deeper planting coming up later will be likely to escape. Other growers make two or three plantings side by side at intervals of a few days apart and after the danger of injury is over they select the planting which gives the greatest promise. The plants in the other plantings are then destroyed.

Planting in hills was formerly the universal practice and is still preferred by some growers, but a large part of the crop is planted in drills. When planted on a large scale planting in hills is seldom practiced at the present time. When the hill method is used the hills are spaced 4 by 5, 5 by 5 or 6 by 6 feet apart depending upon the soil. On light soils of only moderate fertility 4 by 5 feet is sufficient, but in a rich soil a greater space should be given. In the hill system several seeds are planted in each hill and after the plants are well established they are thinned to two plants. The main advantage of the hill method of planting is that the cultivator can be used in both directions. In the drill method the seeds are sown with a seed drill in a continuous row using 2 to 3 pounds to the acre and after the plants are well established they are thinned to stand 12 to 18 inches apart in the row. The rows are spaced 4, 5 or 6 feet apart. The plants are much better distributed in the drill system than in the hill system and much less labor is required in planting.

In some regions cucumber plants are started under cover several weeks prior to the time it would be safe to plant in the open. In the vicinity of Norfolk, Virginia the seed is sown in rows in coldframes as for field culture. When the weather gets warm the sash and the frames are

removed. At this time the vines are usually running and in blossom. Ordinary field cultivation is given after the frames are removed. Market gardeners in the North often start cucumber plants in the greenhouse or hotbed and later set them in the field. The seeds are usually planted in pots, plant bands, veneer bands or tin cans, although they are sometimes started in flats and transplanted to the individual containers while the plants are still small. It is important to have the plants in receptacles so that the roots will not be disturbed when the plants are set in the field. This method of starting plants is practicable only for an early crop which is likely to bring a high price. For the general crop the extra expense of growing the plants in the greenhouse or hotbed would not be justified.

Cultivation.—Frequent shallow cultivation should be given as long as possible without injuring the vines. Weeds should be kept down by cultivation until the vines cover the ground and then large ones should be pulled by hand. Hand hoeing is advisable to keep the weeds down and the soil loose between the plants in the row.

Varieties.—There are very few varieties of cucumbers grown in the United States. The White Spine is the best known and most widely-grown variety. It is grown for all purposes, but is especially prized as a slicing cucumber. Davis Perfect is also a popular slicing cucumber. For pickling Boston Pickling, Chicago Pickling and Fordhook Pickling are considered valuable. For forcing the White Spine, and crosses between this variety and the English forcing type are commonly used. One of these crosses, the Abundance, is a very popular forcing variety in some sections. The English forcing varieties are not very popular in this country, but are grown to some extent in greenhouses on private estates.

Diseases.—Cucumbers are attacked by several serious diseases, any one of which may make production unprofitable. Diseases and insects are the main limiting factors in profitable production of cucumbers in most regions. The most important diseases are bacterial wilt, anthracnose, mosaic, downy mildew and angular leaf spot.

Bacterial Wilt (*Bacillus tracheiphilus*).—This disease, as its name indicates, is caused by bacteria which are carried by insects, especially the striped cucumber beetle. Wilt is usually the first disease to appear in the spring and often causes the plants to wilt and die when they are still small. It may continue to attack the plants throughout the season. A cut stem shows a sticky ooze which will adhere to the finger and can be drawn out into threads. This disease also attacks muskmelons, watermelons, squashes and pumpkins.

Since the disease is carried by insects the control measures consist mainly of keeping them in check. Pulling up and destroying diseased plants as soon as noticed may prevent spread of the disease.

Anthracnose (*Colletotrichum legenarium*).—The anthracnose affects principally the leaves and stems of the plant. On the leaves it causes

brown spots, 1/4 to 1/2 inch in diameter. The older leaves are attacked first and when the disease is serious they are often killed. It spreads rapidly in warm, moist weather and the plants may be killed before the end of the season. This disease also affects muskmelons and watermelons.

Thorough spraying with Bordeaux mixture will hold this disease in check but will not completely control it.

Mosaic.—Mosaic, sometimes called "white pickle," causes a mottling of the leaves, stunting and yellowing of the plants and a warting and mottling of the fruits. The cause of mosaic is unknown, but it is certain that it is carried by insects. Keeping insects under control is the remedy for mosaic.

Downy Mildew (*Plasmopora cubensis*).—This disease attacks the leaves during warm moist weather. Angular yellowish spots appear on the foliage causing a yellowing, followed by curling and death. The oldest leaves are attacked first.

Thorough spraying with Bordeaux mixture, every week or ten days, beginning when the disease first appears will afford control.

Angular Leaf-spot (*Bacterium lachrymans*).—This disease appears as small angular spots, which are at first water-soaked and later turn brown. On the stem the disease appears as lesions somewhat irregular and elongated. It may also appear on the fruits as water-soaked spots.

Treating the seed with corrosive sublimate 1–1,000 for five minutes has been recommended. Spraying with Bordeaux mixture will aid in holding this disease in check.

Insects.—All parts of the cucumber plant are attacked by insects and most of the pests also prey upon other cucurbits. While some of the insects seem to have a preference for a particular species of cucurbits, they will attack others when the one they prefer is not available. Thus the squash vine borer and the squash bug seem to prefer squash and pumpkin plants although they also feed upon the other species.

Britten (16) has prepared a key for quick identification of the insects attacking cucurbitous plants. This key is as follows:

Boring in the roots and stems—
  Small, slender larvae tunneling in the main root or stem below ground.
    Striped cucumber beetle, *diabrotica vitatta.*
  Large, stout larvae boring in squash stems above ground.
    Squash vine borer, *Melittia satyriniformis.*

Devouring the stem and leaves—
  Small (1.2 mm.) purplish, jumping springtails.
    The garden flea or springtail, *Sminthurus hortensis.*
  Small (2 mm.) black, jumping beetles feeding upon the young leaves.
    Cucumber flea beetle, *Epitrix cucumeris.*
  Large (5–7 mm.) yellowish beetles feeding upon the leaves.
    Body yellow, marked with three longitudinal black stripes.
    Striped cucumber beetle, *Diabrotica vitatta.*

Body greenish yellow, marked with twelve black spots.
Twelve-spotted cucumber beetle, *Diabrotica xii-punctata.*
Large (8–10 mm.) hemispherical beetle, orange, marked with black spots, or yellow larva with black spines.
Squash lady-beetle, *Epilachna borealis.*

Sucking sap from the underside of the leaves—
Small dark green or brownish plant lice, often very abundant.
Melon aphis, *Aphis gossipii.*
Large bright green plant lice usually not abundant.
Squash aphis, *Microsiphum cucurbitae.*
Grayish-brown bug with spicy odor (15 mm. when full-grown).
Squash bug, *Anasa tristis.*
Small greenish-white, scale-like insects on the under leaf surface of plants growing under glass or near greenhouses. Pure white, moth-like adults resting on the leaves and flying about.
Greenhouse white-fly, *Asterochiton vaporariorum.*

Striped Cucumber Beetle.—This is probably the most serious insect pest of the cucumber and melon. The beetle attacks the plants as soon as they come up, devouring the leaves and eating the stems. The main injury is done by the overwintering adults attacking the young, tender plants. The beetles also carry the cucumber wilt and mosaic, while the larvae burrow into the roots and cause the plants to wilt, but this injury is seldom noticed.

Among the control measures recommended are (1) covering the plants with cheesecloth-covered frames, (2) destroying old vines and trash at the end of the season, (3) using trap crops and (4) applying repellents and poisons. In addition to these control measures it is advised to plant an excess of seed so that enough plants will be available that some can be saved. Some growers plant double rows and keep one row of plants covered with air slaked lime or other repellent and allow the beetles to feed on the other. Growing plants in greenhouses or hotbeds is a protection as less injury is done to plants of considerable size than to small ones.

Covering with frames is practiced to some extent in home gardens and on small commercial plantings where the crop is grown in hills. This is not a very practical method to use on a large scale.

Burning all of the old vines in the fall will destroy many of the beetles and remove their protection.

Trap crops of squash or beans may be planted early to attract the beetles and they can be poisoned and many killed before the regular crop is planted.

Repellents, such as air-slaked lime, ashes, tobacco dust and Bordeaux mixture have been commonly used. Very often arsenate of lead or other arsenical is applied with the dusts or with the Bordeaux mixture. The arsenical kills many of the beetles, although it does not give complete

control. Recently nicotine-impregnated dust has been recommended. White (181) has reported the results of experiments conducted at the Arlington Farm, Rosslyn, Virginia, in the use of nicotine dust for the control of this pest. As a result of his experiments he recommends a mixture containing 72 pounds of kaolin, 24 pounds of lime and 4 pounds of nicotine sulphate.

He gives the following summary:

> Nicotine sulphate, when applied in a mixture with a dust to young cucumbers, melons, and related crops will protect them from the ravages of the striped cucumber beetle.
>
> A dust mixture containing 4 per cent nicotine sulphate proved as effective as higher percentages of nicotine and is therefore recommended for use against this insect.
>
> One-fourth to one-half of an ounce to the hill proved effective for one application.
>
> The dust acts as a repellent as well as a contact insecticide. When applied properly it drives the insects from the cracks in the soil at the base of the plant, thereby preventing serious injury.
>
> The dust must be applied so as to prevent the beetle from escaping by flight. This can be accomplished by a duster that will throw a good volume of dust quickly with force.
>
> A cheesecloth sack or a knapsack-bellows type of duster is effective on small areas.
>
> Apply the dust to the plant so that it will be covered.
>
> Make the first application as soon as the plants appear above ground. The insect makes its first appearance suddenly and in large numbers and serious damage may result if this application is neglected.
>
> The number of applications depends upon the abundance of the beetles and weather conditions.
>
> Keep the plants and the soil at the base of the plant well covered with dust until all danger of injury is passed. In the vicinity of the District of Columbia this period is normally about three weeks.

Twelve-spotted Cucumber Beetle.—This insect feeds on a large number of food plants, including the cucurbits. On the cucumber and related plants its injury is similar to that of the striped cucumber beetle but it is not as serious in the North. The control measures are the same. The larva is a serious pest of corn in the South where it feeds on the roots, and is known as the southern corn root-worm. It also feeds on roots of other plants, but especially the grasses.

Squash Bug.—This insect is a true bug, which has a very offensive odor, giving rise to the name "stink bug." The adult lives over winter in trash and comes out of hibernation and attacks the plants as soon as they come up. The insects puncture the tissues of the leaves and petioles and suck the juices causing the leaves to wilt. The eggs are brownish in color and are deposited in patches on the underside of the leaves.

There are five stages in the development of this insect and all of them often can be seen on a single leaf.

The adult is resistant to contact sprays. Burning the trash in the fall, trapping the adults under boards in the spring, hand picking of the adults and destroying the eggs are suggested control measures. Spraying with nicotine sprays and dusting with nicotine-impregnated dusts are also recommended.

Squash Vine Borer.—The larva or borer tunnels in the main stem near the surface of the ground and usually decay sets in. The first evidence of injury is the wilting of the entire plant and this is often followed by death. While this insect attacks all cucurbits it prefers squash and pumpkin.

The control measures recommended are: (1) Plant early squash as a trap crop to be destroyed later, (2) cut out borers as soon as there is any evidence of their presence, (3) cover the stems with soil to induce new root-growth, (4) burn old vines as soon as the crop is harvested, (5) plow deeply in the spring to prevent the moths from emerging, and (6) practice crop rotation.

Squash Lady-beetle.—Nearly all lady-beetles are carnivorous and are therefore beneficial rather than injurious, but squash lady-beetle is an exception. The larvae feed upon the underside of the leaves of cucurbits and the adults feed upon the upper side at the same time. This insect seems to prefer the squash and pumpkin, but will feed upon melon and cucumber vines. It is usually a minor pest. If serious, spraying with arsenate of lead or other arsenical is recommended.

Melon Aphis.—The melon aphis, commonly called the "melon louse" is a small sucking insect which injures the plants by sucking the juice. It feeds mostly on the underside of the leaves and often escapes notice until the leaves begin to curl. It attacks a large number of plants, including all of the cucurbits, and cotton in the South. It is less troublesome on squashes and pumpkins than on cucumber and melon plants.

Chittenden (23), 1918, recommends spraying with nicotine sulphate 1–1,000, with soap as a "spreader" or "sticker." His formula is nicotine sulphate, 40 per cent, 3 fluid ounces, yellow laundry soap 1 pound and water 25 gallons. He emphasizes the necessity for thorough spraying to cover the underside of the leaves. Zimmerly, Geise and Willey (190) show that control of this insect was secured in Virginia by using nicotine-impregnated dust containing 3 per cent nicotine. With nicotine 3 per cent and hydrated lime, 98.84 per cent of the aphis were dead 24 hours after dusting cucumber plants.

The Cucumber or Potato Flea Beetle.—This insect injures the plant by eating holes in the leaves. (See Chapter XXIII).

Pickle Worm (*Diaphania nitidalis*).—This is a serious pest of muskmelons, cucumbers and squashes in most sections of the South,

and occasionally occurs in destructive numbers as far north as New York, Michigan and parts of Canada. The young larvae burrow into the tissue of the blossom or bud, and on the squash they may complete their growth in the blossom, but on cucumbers and muskmelons they usually migrate to the fruit. Some burrow down into the stem and complete their growth there and cause injury to the vines, but the greatest injury is caused by burrowing into the fruit.

The newly hatched larva is about $\frac{1}{16}$ inch long and the full-grown caterpillars attain a length of $\frac{3}{5}$ to $\frac{2}{3}$ inch. In some sections of the South there are four, and occasionally five, generations a year.

Spraying with arsenicals has not been successful in controlling this pest. Destroying waste fruits and vines by burning or composting is recommended. Other control measures suggested are planting early so that the crop may be harvested before the second and third broods appear, and growing squash vines as traps.

Harvesting.—Cucumbers are picked on the basis of size rather than age and the size is determined largely by the purpose for which they are grown. When grown for use as slicing cucumbers they are picked when they are 6 to 10 inches long. For pickles they are harvested when they are $2\frac{1}{2}$ to 6 inches long. Very small cucumbers are in demand for mixed pickles, and small to medium-sized ones are preferred for dill pickles. Small-sized cucumbers are less profitable to the grower than the larger ones because of low yields of the former. Frequent picking is important as the cucumbers grow rapidly and soon get beyond the marketable stage. None of the fruits should be allowed to ripen on the vines as the development and maturing of the seeds causes a heavy drain on the plant.

Cucumbers are picked by hand, care being taken to avoid injuring the vine. The stem is left attached to the fruit.

Grading.—Cucumbers for slicing are usually graded on the basis of size, shape and general appearance. The U. S. Bureau of Markets and Crop Estimates suggests three grades, U. S. Fancy No. 1, U. S. No. 1 and U. S. No. 2, with specifications as follows:

U. S. Fancy No. 1 shall consist of cucumbers which are fresh, firm, well shaped, well developed, and have a green color over two-thirds or more of the surface and are free from damage caused by freezing, mosaic, or other disease, insects or mechanical or other means.

In order to allow for variations incident to proper grading and handling not more than 10 per cent, by count, of any lot may be below the requirements for this grade.

U. S. Grade No. 1 shall consist of cucumbers which may be slightly misshapen, but are fresh, firm, well developed and are free from damage caused by freezing, mosaic, or other disease, insects or mechanical or other means.

The same tolerance is allowed for this grade as for U. S. Fancy No. 1.

U. S. Grade No. 2 shall consist of cucumbers which do not meet the requirements of the foregoing grades.

The following marking requirements are also given;

The minimum length or the numerical count of the cucumbers in any package shall be plainly labeled, stenciled or otherwise marked on the package. It shall be stated in terms of whole or half inches as 3 inches min., 3½ inches min., 4 inches min., and so on in accordance with the facts.

In order to allow for variations incident to proper grading and handling not more than 10 per cent, by count, of the cucumbers in any package may be below the minimum length specified.

In addition to the marking requirements and the statement of grade, any lot may be classified as Small, Medium or Large if 90 per cent, by count, of cucumbers conform to the following length requirements for such sizes: "Small," under 6 inches; "Medium," 6 to 9 inches inclusive; "Large," over 9 inches.

For pickles grading rules are usually specified in the contracts, but they are not standard. They are generally based on size, shape and general appearance, the same as slicing cucumbers, except that for pickles smaller sizes are in demand.

Packing.—Cucumbers for market are packed in various kinds of packages, including boxes, baskets, hampers and barrels. Fancy cucumbers, grown in the greenhouse or hotbed, are often packed in special flat boxes, which show them off to good advantage. Flat baskets are also used for fancy grades. Most of the field-grown cucumbers are packed in hampers, mainly of one bushel capacity, but both smaller and larger sizes are used. The round, stave basket holding one bushel, is coming into use and when strong it is a good package. Veneer barrels are still used to some extent, especially for lower grades and for all grades when the prices are low. The barrel is not a good package for cucumbers since it is too large and is not attractive in appearance.

With all types of containers the cucumbers should be well placed and tightly packed so there will be no shifting in the package. Fancy grades, especially of greenhouse cucumbers, are usually placed by hand in the package and attention is given to the attractiveness of the display when the package is opened.

When shipped long distances cucumbers are usually loaded into refrigerator cars under refrigeration. For short hauls local freight and express shipments are common, and refrigeration is not used.

MUSKMELON

The muskmelon or melon is a very popular crop although it is not an easy one to grow in most regions of the United States. It is grown in home gardens, in market gardens in the North, and as a truck crop or special crop in a few of the eastern, southern and western states. It

thrives best and develops the highest flavor in a hot, dry climate, and for these reasons a large part of the commercial crop is produced in California, New Mexico, Arizona and Colorado where the atmosphere is dry during the ripening period. In these states the crop is grown under irrigation. In humid climates the plants grow well, unless injured by diseases and insects, but the fruits do not ripen as well in a normal season as they do in arid regions. If the weather is cloudy or rainy during the ripening period melons are rather insipid. In addition to this, foliage diseases are more serious in humid than in arid regions. Diseases not only reduce the yield but also affect the quality since the fruits do not develop good flavor when most of the foliage has been killed by disease.

The commercial production of the muskmelon is of recent development. Prior to 1870 it was seldom seen on American markets. It was first grown commercially in New Jersey, Delaware and Maryland.

It was not until after the Netted Gem was introduced by Burpee in 1881 that muskmelon culture developed extensively as a trucking industry in regions located long distances from the markets. This type of melon, which is small, round or oval in shape and has a hard rind, is much better adapted to shipping long distances than the varieties previously grown. A large percentage of the crop grown for distant shipping at the present time is of this type.

The muskmelon industry at Rocky Ford, Colorado, began to assume importance about 1896 with the formation of the Rocky Ford Melon Growers' Association. In 1905 the Imperial Valley of California became important as a melon-producing region and is now by far the most important section in the United States.

Statistics of Production.—The muskmelon is an important vegetable, the crop grown for sale in 1919 being valued at $10,766,591. The area of land devoted to the crop was 78,436 acres and the average value per acre was $137. California produced nearly 28 per cent of the entire crop grown in the United States. Table LXI shows the acreage, total value and value per acre of the muskmelons grown in the important producing states in 1919.

Six other states produced over one thousand acres of muskmelons each.

According to McKay, Fischer and Nelson (93) 21,402 cars of muskmelons were shipped in the United States in 1920. About four-fifths of these originated in California, Colorado, Arizona, New Mexico and Nevada. This does not take into consideration local shipments of melons by express nor those hauled direct to local markets by trucks and teams. It does indicate, however, the importance of the western states in melon production.

TABLE LXI.—ACREAGE, TOTAL VALUE, AND VALUE PER ACRE OF MUSKMELONS IN THE IMPORTANT PRODUCING STATES IN 1919
(Bureau of Census)

State	Acres	Total value	Value per acre
California	21,470	$3,895,690	$181
Arkansas	8,999	389,144	43
Maryland	4,665	568,731	122
New Jersey	4,231	371,428	88
Indiana	4,182	498,244	119
Colorado	4,007	691,230	173
Arizona	3,300	465,739	141
Delaware	2,500	203,393	81
Michigan	2,347	465,489	198
North Carolina	2,130	351,543	165
Texas	2,093	189,442	91
Georgia	1,659	157,384	95

History and Taxonomy.—Although the muskmelon has never been found growing wild it is believed to have originated in Asia. It is not of ancient culture as no reference is found to it in the early literature. Columbus found it growing on Isabella Island in 1494 and it is mentioned as being grown in Central America in 1516, in Virginia in 1609, and along the Hudson River in 1629.

The muskmelon, *Cucumis Melo* Linn., belongs to the family Cucurbitaceae and to the same genus as the cucumber. The fact that it is so closely related to the cucumber has led growers to attribute poor quality of the muskmelon to cross-fertilization. This, however, certainly does not normally take place. Many attempts have been made by investigators to produce a hybrid from these two species but without success. Pollen from the cucumber applied to the stigma of the muskmelon flower does not result in fertilization.

Authorities recognize the following botanical varieties of *Cucumis Melo* as proposed by Naudin:

Var. *reticulatus*, netted melons: Fruits small with ribbed and netted surface.

Var. *cantalupensis*, cantaloupe melons: Fruits warty, scaly and rough, with hard rinds, surface often warted. This type is practically unknown in the United States. The name cantaloupe is improperly applied to melons in general, or to certain types.

Var. *inodorous*, winter melon, Cassaba melon: Fruit with little of the musky odor, ripening late and keeping into the winter; surface usually smooth.

Var. *flexuosus*, snake or serpent melon: Fruit long and slender, 1 to 3 inches in diameter and 18 to 36 inches long, curved and crooked. Used to some extent for preserves, but grown mostly as a curiosity.

Var. *Dudain:* Fruit small, about the size of an ordinary orange, surface marbled with rich brown, very fragrant; grown mostly for ornament and strong scent.

Var. *Chito:* Mango melon or lemon cucumber; fruit small, the size of a lemon, used in making preserves, called mango preserves. The fruits are known as orange melon, melon apple and vegetable orange.

The melons commonly grown in the United States belong to *Cucumis Melo*, var. *reticulatus*. All of the varieties commonly seen on the market, with the exception of the cassaba, belong here.

Soil Preferences.—Muskmelons are grown on a great variety of soil types. Where earliness is an important factor, as in most regions of the North, a sandy loam is considered the best. In fact, this type of soil is considered almost ideal in most regions, although other soils are used in regions where the growing season is long. The soil should be well drained, as melons do not thrive on a water-logged soil. Any friable, well-drained soil is satisfactory provided the other conditions are favorable to melon growing.

Manures and Fertilizers.—Manure is considered very valuable in growing muskmelons and many growers in the North believe that the crop cannot be grown successfully without it. Very little experimental evidence is available on this subject although Lloyd (87) has reported results of experiments carried on at Anna, Illinois, for 3 years and at Kinmundy, Illinois, for 5 years. The soil at Anna is an unglaciated yellow silt loam and at Kinmundy a gray silt loam. The plats consisted of 4 rows of 16 hills each or 64 hills.

Lloyd gives the following general conclusions as a result of these experiments:

1. Under the conditions of these experiments manuring in the hill is far superior to broadcast manuring unless a very large amount of manure can be used.

2. A large amount of manure used in the hill is conducive to the production of a large yield of early melons, but a small amount of manure (2.25 to 3 tons per acre) carefully applied to the hills produces a greater net profit than a larger amount (4.5 to 12 tons) applied in a similar manner, or still larger amounts (16 to 20 tons) applied broadcast, even though the yields are somewhat smaller.

3. Although the highest average yield in the field-planted crop and the second highest in the transplanted crop were produced by the plats receiving manure both broadcast and in the hills the expense of so much manure may so reduce the profits that they will be less than from some other treatment.

4. Mixing the manure with the soil in the hill, although it increases the labor of planting the crop, has no apparent advantage over applications of the

the same amount applied without mixing, except possibly in the case of a large amount applied to the transplanted crop.

5. The addition of raw rock phosphate to a moderate amount of manure in the hills may increase the yield of early melons, the total yield and the net profits in the field-planted crop.

6. The use of a complete fertilizer applied broadcast in addition to manure in the hill is conducive to the production of large total yields but the high cost of this fertilizer may render its use inadvisable.

7. The application of this same fertilizer in hills in lieu of manure is attended with great danger, especially to the field-planted crop and may greatly reduce the yield as compared to no fertilizer treatment.

8. A fair crop of melons may sometimes be produced by the use of steamed bone alone in the hills, though the results are less satisfactory than from the use of manure, especially in the field-planted crop.

9. On the type of soil and with the cultural methods used for the field-planted crop in these experiments it is unwise to attempt to produce a crop of melons without the application of plant food.

A considerable percentage of the muskmelon crop is grown without manure, because of the expense and the difficulty of securing a supply. In the South and West dependence is placed on commercial fertilizers and green-manure crops. Production can be maintained without manure if the soil is kept supplied with humus, and a sufficient amount of the various elements is supplied in the form of commercial fertilizers. Where no manure is used 1,000 to 2,000 pounds of commercial fertilizer, containing 2 to 4 per cent nitrogen, 8 per cent phosphoric acid and 4 to 8 per cent potash, is recommended. The amount and formula should be determined largely by the kind of soil. On a sandy soil, deficient in potash, the higher percentage of this element should be used, but on a soil containing considerable clay the lower amount will be sufficient. Recommendations of various authorities range from 500 to 2,000 pounds of a high-grade complete fertilizer to the acre.

Application of the fertilizer in hills or in the furrow is recommended where the amount is 500 pounds or less to the acre. For larger amounts than 500 pounds broadcast application is recommended by most writers, although some suggest applying part broadcast and part in the hills or rows. Where as much as 1,000 pounds to the acre are used no advantage would result from applying part of the fertilizer in the hill, since sufficient would be within reach of the plant to provide for its needs while it is small, even with the broadcast application. As the plant grows the roots reach out so that the feeding area increases as the needs of the plant increase.

Growing Plants.—A large part of the muskmelon crop grown in regions having a short growing season, is produced from plants started in greenhouses, hotbeds, or cold frames. The seeds are usually planted in pots, plant bands, or other receptacles, since the seedlings do not with-

stand the shock of transplanting well when they attain considerable size. Several seeds are planted in each receptacle and the plants are thinned to one or two when they are well established. Some growers prefer to sow the seed in flats. Five to seven days later, when the seed leaves have developed, but before the first true leaves appear, the seedlings are transplanted into pots, plant bands or other receptacles, one plant to each. It is very important to transplant the plants while they are very small, otherwise growth will be seriously checked and many plants will not survive. This is one reason that planting the seed in pots or bands is generally recommended.

Planting in the Field.—Muskmelon plants are very tender and the seeds will not germinate at low temperatures, hence planting in the field should be delayed until all danger of frost is over and the soil has become warm. Plants should be set before they develop more than four leaves and before they become pot-bound, and for this reason the seeds should not be planted more than 4 or 5 weeks before it is safe to set them in the field.

A large part of the commercial crop is grown from seed planted in the field. While the hill method is still used, drilling the seed is the more common practice in large plantings at present. The methods of planting in hills and in drills are practically the same as described for the cucumber. When planted in drills the usual rate of planting is 2 to 3 pounds of seed to the acre.

Cultivation.—Frequent shallow cultivation should be given until the vines interfere with the operation. Some growers continue cultivation after the vines meet between the rows, but it is probable that more harm than good is done since the plants are easily injured. Moving the ends of the vine with a stick may be justified, but turning them from one row to the other may seriously injure them. Cultivation after the vines cover a considerable portion of the ground is probably of little, if any value unless weed growth is heavy. Large weeds may be pulled by hand after cultivation ceases. Hand hoeing in the row may be desirable while the plants are small.

Varieties.—Simple methods of classifying varieties of muskmelons into a few groups or classes have been suggested by various workers. One method is based on color of flesh, separating varieties into groups: (1) Those with green or white flesh and (2) those with salmon or yellowish flesh. This method is not of much value since separating the varieties into two groups is no great help in identification. Other methods of classification that have been suggested are based on size, shape, color, and smoothness of the surface—whether netted or not netted, ribbed or not ribbed. Rane (121) proposed a system based mainly on size and shape. Under this system the varieties are divided into eight groups or types as follows:

1. Jenny Lind Type.—"Small size, flattened at ends, average weight less than 2¾ pounds." This class includes Jenny Lind, Jersey Belle and Emerald Gem.

2. Rocky Ford Type.—"Small size, oval shape, average weight less than 2¾ pounds." This includes Rocky Ford, Netted Gem, Rose Gem, Paul Rose.

3. Hackensack Type.—"Medium size, flattened at ends, average weight 3 to 6 pounds." This includes Nutmeg, Irondequoit, Ivy Gem, Hackensack, Surprise and many others.

4. Montreal Type.—"Medium size, oval shape, ribbed, average weight 3 to 6 pounds." This type includes Montreal Nutmeg, Green Fleshed Osage, Millers Cream, Tip Top, etc.

5. Cosmopolitan Type.—"Medium size, oval shape, no ribs, average weight 3 to 6 pounds." Cosmopolitan, Netted Beauty, Superior and other little-known varieties are included in this type.

6. Acme-Osage Type.—"Medium size, oblong shape, average weight 3 to 6 pounds." Osage, Anne Arundel, Acme and Delmonico are the best known varieties included in this type.

7. Long Yellow Type.—"Large size, oblong shape, average over 6 pounds." This includes Banana, Granite State and Long Yellow.

8. Bay View Type.—"Large size, oval to oblong shape, average over 6 pounds." Bay View, Large Black Paris, Montreal Market and Large White French belong to this class.

This classification is of little value at the present time as many of the varieties are no longer grown and in many other cases the names have been changed. Any method of classification based on size is of little value at best, since the environment is such an important factor in determining size. Under this classification any type may include varieties possessing such opposing characters as ribbed and not ribbed; netted and not netted; green and salmon fleshed. Since these characters are inherited it would seem that they should be the main ones used as a basis of separation in any method of classification.

In selecting varieties of muskmelons for market the grower should take into consideration the demands of the consumer, especially with reference to size of melon, color of flesh, quality and surface markings. After determining the consumers' preferences he should consider varieties with reference to yield, disease resistance, earliness, shipping quality, keeping quality and other factors that might affect profits. Some varieties of high quality are poor shippers and for that reason are adapted only for home use and for local markets. Others are excellent shippers, but of low quality. For long-distance shipping the varieties should possess good shipping qualities, such as a thick rind, relatively solid flesh and slow ripening, uniform size and shape, but at the same time they should be of good quality. The following are among the most important varieties:

Pollock (Pollock 10–25, Pollock No. 25, Salmon Tinted Pollock), the most important commercial variety grown in the United States, is produced extensively in California, Colorado, New Mexico, Arizona and Nevada. It is an early variety, small, nearly round, heavily netted, not ribbed, a good shipper, and a heavy yielder. The flesh is thick, salmon colored, and of good quality.

Rocky Ford.—This variety was developed from the Netted Gem introduced by Burpee in 1881. The melon is nearly round or slightly oval, not ribbed, heavily netted; skin green, netting nearly white; flesh green, fine texture and good flavor. Strains of this variety are popular in many regions.

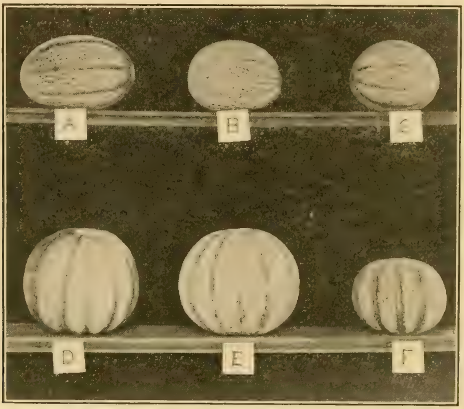

Fig. 30.—Varieties of muskmelons—A, Burrell Gem; B, Rocky Ford; C, Paul Rose; D, Irondequoit; E, Bender's Surprise; F, Round Jenny Lind.

Jenny Lind.—One of the smallest melons, flattened at the ends with knob at the blossom end, ribbed and netted; flesh thin, green in color, fine in texture, and very sweet. This is an old variety of high quality, but is grown to a very limited extent at the present time.

Netted Gem.—See Rocky Ford.

Burrell Gem.—(Also called Pink Meat) This variety was introduced by Burrell in 1904. The fruit is oblong, sloping toward both ends, ribbed, netted, skin dark green; flesh deep orange or salmon in color, thick, fine grained and of good quality. This variety is a good shipper, but is not a desirable one for humid regions as the fruits crack badly in wet weather.

Hackensack—This is an old variety of good size (5 to 8 pounds). Fruit heavily ribbed, netted; flesh light green, quite thick, good flavor. This is not an important variety at present, except for local markets since it is too large to ship well.

EMERALD GEM.—A small flat melon, early in maturing and of high quality. It is a good home-garden variety and is grown to some extent by market gardeners, but it is not a good commercial variety because it goes down rapidly in hot weather. The fruits are ribbed, green in color, smooth (not netted); flesh thick, salmon colored and sweet.

OSAGE OR MILLER'S CREAM.—Medium in size, oblong; skin dark green, lighter between the ribs; flesh thick, firm, orange or salmon colored, good quality. This is an old variety, but is still grown to some extent by market gardeners.

FIG. 31.—Varieties of muskmelons—A, Angelo; B, Milwaukee Market; C, Hackensack; D, Jenny Lind; E, Emerald Gem; F, Miller's Cream.

TIP TOP.—Medium to large size, oval in shape; skin slate colored, partly netted: flesh deep salmon, good quality. This is also an old variety grown only to a slight extent at present.

PAUL ROSE.—Medium size oval in shape; flesh deep orange. It is supposed to be a cross between Netted Gem and Osage. Not an important variety at the present time.

IRONDEQUOIT.—Large (8 to 10 pounds), nearly round; skin green, but yellowish when ripe, well netted; flesh deep orange thick, sweet and good flavor. This variety originated at Irondequoit, New York, and was grown quite extensively by market gardeners a few years ago, but is now largely replaced by Bender's Surprise, because it does not hold up well on the market and has a tendency to crack.

BENDER'S SURPRISE.—Large, oval shape, medium early, skin light green turning to a golden tint on ripening, coarse netting; flesh firm, thick, deep orange color, good flavor. This variety was originated and devel-

oped by Mr. Bender, a market gardener living near Albany, New York. It is by far the most important variety grown in New York, constituting probably 90 per cent of the commercially-grown crop.

Montreal Market.—Very large (8 to 15 pounds), nearly round, flattened at the ends, regularly ribbed; skin green, heavily netted; flesh very thick, light green, flavor good. This variety is grown to only a very limited extent in the United States. In the vicinity of Montreal, Canada, the growing of this variety for the markets of New York, Boston, Philadelphia and other eastern cities has attained considerable importance. Greater skill is required to grow this variety than to grow the varieties commonly produced in the United States. (For a comprehensive discussion of the culture of this variety of muskmelon read Vermont Experiment Station *Bull.* 169.)

Cassaba.—The name Cassaba is commonly applied to a type of melon grown in California, and to some extent in other western states, for fall and early winter use. The fruit is medium in size, round to slightly oval and the surface is smooth or nearly so (no netting) and greenish-white to yellow in color. The flesh is thick, greenish-white in color and of good texture. Varieties listed by American seedsmen include Cassaba, Honey Dew, Hungarian Cassaba, Golden Beauty, Pineapple, Golden Honey Cassaba and several so-called hybrids, including Golden Hybrid and Improved Hybrid.

Cassaba melons thrive best in a warm, dry climate and have not been successfully grown in the humid regions of the United States.

Diseases.—The muskmelon is attacked by the same diseases as the cucumber and the same methods of control may be applied.

Insects.—All of the insects discussed under "cucumber" also attack the muskmelon, and the same methods of control are recommended. In addition to those attacking the cucumber the melon worm (*Diaphania hyalinata*) is often injurious to melons in the South and occasionally as far north as New York and Michigan. The adult is a moth with white wings marked with a brown band along the margins. The full-grown caterpillar is about one inch long, and greenish-yellow in color, somewhat mottled. The first brood feeds on the foliage and does little damage to the fruit. The larvae of the later generations attack the fruit, feeding on the surface and burrowing through the rind. Decay sets in almost immediately and the fruits are worthless. The control measures suggested are: (1) Plant squashes ahead of the melons to serve as a trap crop; (2) spray with arsenate of lead, three pounds of paste to 50 gallons of water and (3) destroy the vines and waste fruits as soon as the crop is harvested.

Harvesting.—The time of picking melons depends mainly upon the distance from market, but also to some extent upon the variety, the temperature at harvest time and the method of shipping. For local

markets the fruits should be left on the vines until they are fully ripe but still solid. When the melons are to be shipped they are picked before they are fully ripe. For relatively short hauls, and for long hauls during comparatively cool weather, they may be picked when they separate readily from the stem. This stage is known as the "full-slip." When they are to be in transit 10 days or more it is best to pick the melons before they reach the full-slip stage of maturity. Results of studies reported by McKay, Fischer and Nelson (93) on melons shipped from points in California to New York City during 1916 and 1917 show the importance of picking at the proper time. They state that fully 10 per cent of the melons shipped from the western states in 1915, 1916 and 1917 were so immature when placed upon the market that they were not palatable nor even of fair eating quality. Green melons have a depressing effect upon both demand and prices, so that the best judgment should be exercised by pickers in selecting melons of the proper stage of maturity. No definite rule can be given as to the best time to pick melons, but by cutting a few specimens pickers can familiarize themselves with the condition of the fruit. The ease with which the fruits are separated from the stem is probably the best method of determining the stage of maturity.

Careful and prompt handling after the melons are picked is very important. Rough handling causes bruising which makes them more susceptible to decay. Delay in getting the melons packed and loaded into refrigerator cars may result in too rapid ripening with consequent loss on the market. Table LXII shows the effects of delayed loading of muskmelons in the Imperial Valley on their condition on arrival in New York City as reported by McKay, Fischer and Nelson (93). The figures are based on 13 shipments of comparable lots.

Table LXII.—Condition of Muskmelons (Pollock) Held 1, 4 and 8 Hours before Loading into Refrigerator Cars, on Unloading in New York City, and Two Days Later, 1917

Condition of melons	On unloading			Two days later		
	1 hr., per cent	4 hr., per cent	8 hr., per cent	1 hr., per cent	4 hr., per cent	8 hr., per cent
Too soft to be desirable..........	8.4	16.7	27.0	30.6	34.7	43.2
Too yellow—overripe............	8.4	13.3	15.0	20.9	21.5	26.3
Decayed enough to spoil for food..	...	....	1.2	2.9	3.3	4.4

Grading.—No uniform and specific grading rules are in use in most muskmelon growing sections, although the fruits are usually graded to some extent. The grading is more satisfactory in some regions than in

others. Western-grown melons are usually better graded than those grown in the East, but none are as well graded as they should be. The fruits should be carefully graded with reference to size, shape, color and general appearance. Fully ripe melons should be packed separately and disposed of on nearby markets, as they will not stand long distance shipping. Soft, green, off-type, bruised, and very small melons should be discarded, and only those that will reach the market in good condition should be packed.

Packing.—Muskmelons for local markets are seldom packed, but those that are to be shipped are always put up in packages of some kind. Crates of various sizes, holding from 12 to 54 melons, are the most popular type of package. Downing (38) gives dimensions of 16 crates that are in common use in the United States. These range in size from 4 by 12 by 22½ inches inside dimensions in the California pony flat crate to 12 by 12 by 22½ inches for the California standard crate. Downing states that the large number of sizes could be reduced to six, possibly to four types without interfering with the standard pack. The suggested sizes are:

	Inches
Standard	12 × 12 × 22½
Pony	11 × 11 × 22½
Standard flat	4½ × 13½ × 22½
Pony flat	4 × 12 × 22½
Jumbo	13 × 13 × 22½
Jumbo flat	5 × 14½ × 22½

Reducing the number of sizes would eliminate much confusion and at the same time reduce the expense of manufacture.

In packing melons in the standard crate they are placed three wide, three deep and four or five long, the crate holding 36 or 45 fruits. Smaller melons are packed in the pony crate in the same way except that six melons are sometimes placed in a row lengthwise of the crate. The standard flat crate holds 12 to 15 melons; one layer deep, three melons wide and four or five long. It is important that the melons in each type of crate be of uniform size. When the crate is packed every melon on each side should touch the slats and the crate when covered should bulge slightly on all sides. Unless there is a slight bulge when the melons are packed the pack is loose when it reaches the market and the fruits are likely to be bruised by shaking about in the crate.

Wrapping muskmelons in paper is practiced to some extent, but is not to be recommended as the paper excludes the air, keeps the surface moist, delays refrigeration and discourages inspection. Results of experimental shipments of wrapped and unwrapped melons shipped from the Imperial Valley, California, to New York City, have

been reported in Farmers *Bull.* 1145. The results are shown in Table LXIII.

TABLE LXIII.—CONDITION OF 13 EXPERIMENTAL SHIPMENTS OF WRAPPED AND UNWRAPPED MUSKMELONS IN NEW YORK, ON UNLOADING AND TWO DAYS LATER, SEASON 1917

Condition of melons	On unloading		Two days later	
	Wrapped, per cent	Unwrapped, per cent	Wrapped, per cent	Unwrapped, per cent
Too soft to be desirable	17.7	15.3	28.8	34.0
Too yellow—overripe	8.7	4.6	17.7	2.7
Decayed enough to spoil for food	0.5	0.0	22.7	4.6
Molded enough to affect appearance	3.1	0.2	42.4	2.7

Two days after unloading from refrigerator cars the wrapped melons were slightly firmer than the unwrapped, because loss of moisture was less from the former than from the latter. The difference, however, was slight and did not compensate for the increase in decay and mold resulting from wrapping. Wrapped melons cool more slowly than those not wrapped because the paper retards circulation of cold air and acts to some extent as an insulator.

WATERMELON

The watermelon requires a long, and relatively hot growing season for its best development and for this reason it is grown largely in the South. However, the crop can be grown successfully in many of the northern states if early-maturing varieties are selected. In regions having a short growing season (4 months or less) watermelons can be produced only if the plants are started in greenhouses or hotbeds a few weeks prior to time for planting in the field.

The watermelon is grown in many countries, but is more popular in the United States than elsewhere. It is used mainly as a dessert, but the rind is used to some extent in making conserves and pickles.

Statistics of Production.—The watermelon is one of the important truck crops, especially in the southern states. In 1919 the value of the crop grown for sale was $10,466,133 and 159,088 acres of land were devoted to its production. While a very large part of the crop was grown in the southern states, it was of considerable importance in Missouri, California, Indiana, Kansas, Illinois, Iowa and Maryland. Three states, Georgia, Texas and Florida produced over 40 per cent of the watermelons grown in the United States in 1919 as is shown in Table LXIV.

Table LXIV.—Acreage, Total Value and Average Value per Acre of Watermelons Grown in Important Producing States in 1919
(Census Report, 1920)

State	Acreage harvested	Total value	Value per acre
Georgia	29,091	$ 1,300,553	$45
Texas	22,564	1,064,106	47
Florida	14,646	993,409	68
Missouri	9,249	615,696	67
South Carolina	7,779	394,461	51
Oklahoma	7,534	410,771	55
California	7,341	619,485	84
Alabama	6,088	318,093	52
North Carolina	5,983	414,762	69
Indiana	4,850	446,902	92
Virginia	4,730	415,791	88
Arkansas	4,717	319,684	68
Kansas	4,400	357,031	81
Illinois	3,852	289,605	75
Iowa	3,475	279,721	80
Tennessee	3,350	312,895	93
Maryland	3,005	221,743	74
United States	159,088	10,466,133	66

Origin and History.—The watermelon is a native of Africa where it has been found growing wild in recent times (David Livingstone, Trav. Res. South Africa, 54, 1848). It was mentioned by European botanists in the sixteenth century and is said to have been introduced into Great Britain in 1597. It was grown in Massachusetts as early as 1629 and by the Florida Indians prior to 1664.

Soil Preferences.—The watermelon thrives best on a sandy loam soil, although other loams are used for the production of this crop in the South. In regions having a short growing season only the lighter soils should be used for this crop. Good drainage is essential for best results in growing watermelons as they will not thrive in a water-logged or poorly-drained soil.

Planting.—The time and method of planting watermelons are practically the same as for muskmelons, except that they require more room and a longer growing season. In regions having less than four months' frost-free period watermelons cannot be grown successfully unless the plants are started under protection three or four weeks prior to the time it is safe to plant them in the field. Under most conditions, watermelon production is not profitable where it is necessary to start the plants under cover in order to mature the fruit before frost in the fall. For home use

and for special markets starting plants in greenhouses, hotbeds or under plant forcers may be justified. When the plants are to be grown in greenhouses or hotbeds it is best to plant the seeds in plant bands, flower pots, or other receptacles as the seedlings do not withstand transplanting very well. Several seeds are planted in each receptacle and when the seedlings begin to crowd they are thinned to a single plant, or two or three plants in each.

Nearly all of the commercial crop is grown from seed planted in the field. These are planted 10 to 15 in a hill with the hills spaced 8 by 8, 8 by 10 or 10 by 10 feet apart each way, or they are drilled an inch or two apart in rows 8 to 10 or even 12 feet apart. In either case the seeds are covered to the depth of 1 or 2 inches. The drill method is the more common in large plantings. In the hill method the plants are thinned to 2, 3 or 4, to each hill as soon as they are well established and the danger of destruction by the cucumber beetle is past. When the seeds are planted in drills the plants are thinned to stand singly 2 to 3 feet apart in the row. With this method there is a better distribution of plants over the area than in the hill system. Plants started in greenhouses or hotbeds may be planted either in hills or in drills. When setting them in the field the work should be done carefully to avoid disturbing the roots.

When manure is used in growing watermelons it is a common practice to apply some or all of it in the furrow or under the hill. In either case the manure is covered with loose soil to the depth of 2 or 3 inches. It is claimed that the manure hastens the germination of the seeds and the development of the seedlings. This is undoubtedly true where fresh manure is used as this undergoes heating and warms the soil. In the South this is of little consequence, but in regions having a short growing season hastening germination and growth may be very important.

The amount of seed required depends upon the method of planting. When planted in hills the usual rate is 2 to 3 pounds to the acre, while in the drill method 4 to 5 pounds are ordinarily used. It is advisable to use a liberal quantity as the cucumber beetle often destroys a large percentage of the plants.

Cultivation.—Watermelons should be given about the same cultivation as cucumbers and muskmelons. When the plants are small the soil may be stirred with a harrow run between the rows. In the hill method of growing the harrow may be run in both directions, leaving only a small amount of space at the intersections that would need to be hand hoed. After the plants grow to considerable length, but before they meet in the middles, a small cultivator should be used instead of the large harrow. When the vines meet cultivation usually ceases, but large weeds should be pulled by hand.

Varieties.—Rane (122) classified the varieties of watermelons into six classes or groups based on the external characters of the fruit. The

classes were subdivided into types based on shape. The classification is as follows:

1. Light green class
   A. Sweet Heart Type—Oval
   B. Monarch Type—Long
2. Medium Green Class
   A. Icing Type—Oval
   B. Jackson Type—Long
3. Dark Green Class
   A. Black Spanish Type—Oval
   B. Boss Type—Long
4. Light Striped Class
   A. Kolb's Gem Type—Oval
   B. Cuban Queen Type—Medium
   C. Rattlesnake Type—Long
5. Dull Striped Class
   A. Pride of Georgia Type—Oval
   B. Christmas Type—Medium
   C. Favorite Type—Long
6. Mottled Green Class
   A. Nabob Type—Oval
   B. Phinney Type—Oblong

In selecting varieties of watermelons for planting one should consider the purpose for which the crop is grown. If grown for home use, or for a local market quality should be the first consideration, but size, shape, yield and other factors must also be considered. When grown for shipment the melons must be solid and have a relatively thick rind or there will be serious losses in handling due to breakage. The grower, however, should not lose sight of the importance of quality, for low quality limits consumption and lowers the price. A good market melon is one which stands shipment well and is of good quality. There is more demand for small to medium-sized melons than for very large fruits. In selecting varieties for planting in regions having a short growing season earliness is an essential. The following varieties are among the most important, although no attempt is made to list them in the order of their importance:

Cole's Early.—This is a small, round, white or grayish melon with green stripes; rind thin; flesh light pink, crisp and of good flavor. It is an early variety suitable for home use and for local markets, but since it is very brittle it is not satisfactory for shipping.

Fordhook Early.—Medium in size, round, dark green in color, sometimes with faint stripes of light green; rind thin; flesh light red, crisp, quality good. This is a good variety for home gardens and for local markets in the North since it is early, but it is not a good shipper.

Kleckley Sweet.—Medium to large size, oblong in shape; dark green in color; rind thin; flesh bright red, firm and solid, quality excellent. This variety has been considered one of the very best for home

gardens, and is satisfactory for local markets, but does not stand shipment and rough handling.

Halbert Honey.—Medium to large size, oblong in shape, dark green in color; rind thin and brittle; flesh red, fine texture, good quality. This melon is early and is excellent for home use and for local markets, but because it has a thin, brittle rind it is not satisfactory for shipping.

Florida Favorite.—Medium to large size, oblong, dark green irregularly striped with still darker green. Rind of medium thickness; rather tough; flesh deep red and of fair quality. This variety is fairly early and a fair shipper.

Rattlesnake (Augusta Rattlesnake, Georgia Rattlesnake). Large in size, long, light green with dark green longitudinal stripes; rind thick and solid; flesh red, crisp, tender, quality good. This is a very popular shipping variety and is one of the best in quality of those that stand shipping and rough handling.

Tom Watson.—Large in size, long, dark green in color; rind medium in thickness but tough; flesh deep red, quality only fair. This is one of the most important, if not the most important shipping variety.

Kolb Gem.—Large, round or oval in shape; rind very thick and tough; flesh stringy and coarse, but well flavored and quite sweet. This variety is fairly early, an excellent shipper, quality fairly good, though coarse in texture.

Alabama Sweet.—Large in size, oblong, similar in appearance to Florida Favorite; rind medium thick; flesh deep red, fine grained, solid and sweet. This variety is considered by some as one of the best for shipping purposes and is also mentioned as being satisfactory for home use and for local markets.

Other varieties that deserve mention are Jones, McIver, Cuban Queen, Monarch and Irish Grey The last one is a relatively new name and may be a new variety of merit.

Preserving Melon or Citron.—This fruit resembles a small watermelon, of light green color, usually round or oval in form. The flesh is white in color and is not edible. The rind is used for making conserves and sweet pickles, and the melon is sometimes fed to hogs. It is also known as "stockmelon."

The preserving melon has about the same cultural requirements as the watermelon. It crosses readily with the watermelon and has been used in breeding to produce a wilt-resistant watermelon.

Diseases.—The watermelon is attacked by a number of diseases, the most important ones being wilt, root-knot, anthracnose, stem-end rot, blossom-end rot and ground rot. Both the vines and fruit are affected. Orton (112) gives the following descriptive key to watermelon diseases:

A. The vines wilt suddenly, beginning at the ends of the branches........Wilt
B. The vines lack vigor and the melons remain small; roots greatly enlarged
Root-knot
C. The leaves show dark spots and tend to shrivel up............Anthracnose
D. The fruit is spotted with small pits...........................Anthracnose
E. The fruit decays at the stem end..........................Stem-end rot
F. The fruit decays at the blossom end......................Blossom-end rot
G. The fruit decays where it rests on the ground, with abundant white mold
Ground rot

Wilt (*Fusarium niveum*).—Vines affected by this disease wilt suddenly, beginning at the tips of the branches. One branch after another wilts until the whole plant is dead. The woody portion of the stem is discolored. The organism lives in the soil and grows up through the water-conducting tissues. These become plugged and the vine wilts.

No satisfactory method of control has been discovered, but Orton states that the following measures have been found to be of importance: (1) Rotation of crops; (2) control of drainage water to prevent water from an infected field running over an uninfected field; (3) avoidance of stable manure; (4) control of livestock and (5) resistant varieties. When land becomes infected with the wilt organism it should not be used again for melons for 8 to 10 or 12 years. The organism grows well in stable manure hence its use is not advised where wilt is serious. In addition to this many stables become infected from portions of vines brought in with hay cut from the melon fields after the crop is off. Livestock may spread the wilt if they are allowed to range from an old melon field to other fields which may be planted to melons later. There is no commercial variety of watermelon that is very resistant to the wilt. The United States Department of Agriculture has produced a wilt-resistant melon by crossing the Eden with the stock melon or citron and the North Carolina Agricultural Experiment Station, by a similar method, has also produced a wilt-resistant variety. Neither of these varieties is recommended for general use.

Root-knot.—This disease is produced by a species of nematode (*Heterodera radicicola*) widely distributed in the South, and very destructive to many vegetables and other crops. For a discussion of the symptoms of the disease and the control measures read the discussion under cabbage, Chapter XX.

Anthracnose (*Colletotrichum lagenarium*).—The anthracnose is one of the most troublesome diseases of the watermelon. It affects the leaves, vines and fruit. On the leaves and stems the disease appears as irregular dark spots. The leaves dry up and die prematurely. On the fruits the spots appear at first as water-soaked areas, but later they are sunken and covered with a pink growth of spores. These spots are usually small and there may be hundreds on a single fruit. At first they are shallow, but

become deeper and may result in the decay of the flesh when followed by other fungi.

Spraying the vines with 4–4–50 Bordeaux mixture is the most practicable method of controlling this disease according to Meier (95), who has made a considerable study of anthracnose. He recommends three applications, the first when the vines begin to run, the second about one week after the melons have "set" and the third about two weeks after the second. Other measures suggested are the use of anthracnose-free seed, rotation of crops, and avoidance of cultivating when the vines are wet.

Stem-end Rot (*Diplodia sp.*).—This is a disease which affects the fruit at all stages of development and may cause serious loss in transit even if it does not show at the time of loading. The first indication of the disease is a browning and shriveling of the stem. Decay of the fruit begins at the point of attachment of the stem. The flesh becomes soft and takes on a water-soaked appearance. The decay progresses rapidly and under moist conditions it becomes covered with a dark gray mold. The same type of decay may begin on the side of the melon where there is an injury.

Orton (112) suggests the following control measures: (1) Clean up the fields; (2) gather and destroy all cull melons; (3) spray for anthracnose, as the fungus which causes stem-end rot does not attack a healthy vine, but will grow on leaves and stems killed by anthracnose and thence be carried to the melons; (4) use great care to prevent injury in handling and (5) disinfect the stem at the car. The disinfection of the stem at the time of loading the car is the most important control measure. The material used for disinfection is starch paste with copper sulphate. Orton suggests the following method of preparation and application of the paste:

Place 3½ quarts of water and 8 ounces of bluestone in the kettle and bring the mixture to a boil over a good fire. While it is heating, mix 4 ounces of starch with a pint of cold water, stirring until a milky solution free from lumps is obtained. As soon as the bluestone is entirely dissolved and the solution boiling, add the starch mixture, pouring it in a slow stream and stirring the hot solution vigorously to prevent the formation of lumps. Continue boiling and stirring the mixture until the starch thickens evenly. It may be tested at intervals by allowing it to run from the end of the paddle. This should not require more than one or two minutes' boiling after the addition of the starch.

The paste seems to be more readily applied when made up fresh, but if it is desired to make up a quantity at one time it may be depended upon to keep a week or two by using only one-fourth to one-half the proportion of water previously specified and then diluting the resultant thicker paste to the proper consistency as needed for use. Quart glass fruit jars with glass or enamel lined tops make convenient containers.

It is recommended that this be applied at the car, for experiments with stem treatment in the field were less effective because the handling rubbed off the

paste or split the stem. The following method has proved to be practical and effective.

As the melons are packed in the car, have the stem ends turned outward while a second man or boy with a sharp knife cuts off a portion of the stem and applies a dab of paste to the fresh surface. One man can accomplish this treatment without interfering with the speed of loading and can keep up with two packers. A quart of paste, costing only a few cents, will be needed for each car. To this expense must be added the labor cost of one boy or man for the number of hours required to load the car.

Blossom-end Rot.—This disease is common in many fields, but little is known about it. According to Orton it begins (or seems to begin) with an imperfect fruit. Later these fruits are invaded by decay-producing fungi. The Diplodia or stem-end rot is the most common, but other fungi also occur. Prompt destruction of cull melons is the control measure suggested.

Ground Rot (*Sclerotium rolfsii*).—This rot begins on the side of the melon in contact with the soil. The fungus causing this disease is very common in the South and attacks many other plants. A heavy growth of white mold and the formation of many, roundish brown bodies the size of buckshot characterize this disease. Decay begins where there is an injury to the surface of the melon. The only control measure is the destruction of the affected fruits.

Insects.—The watermelon is affected by the same insects as the cucumber. The melon aphis is more injurious to the watermelon than to either the cucumber or muskmelon. For a discussion of the insect pests of the watermelon see under "Cucumber."

Harvesting.—It is very important that watermelons be at the proper stage of maturity when they are picked, but it is very difficult for the inexperienced to determine when they are ripe. With no other vegetable or fruit is there so little evidence of a change from immaturity to maturity. Neither the size of the fruit nor the color of the rind gives an indication of ripeness. Perhaps the sound emitted when the fruit is thumped with the finger is the most reliable means to determine the stage of ripeness of watermelons. Most varieties give forth a metallic, ringing sound when they are green and a more muffled or dead sound as they become more mature. The greener the melon the more metallic the sound. The sound is not the same for all varieties so that some should be pulled when they still give forth a somewhat metallic sound, while others should be left on the vines until the sound is quite a dead one. It is only by experience that one becomes able to select the ripe fruits, but with precaution and by cutting a melon occasionally the knack is quite readily acquired. The fruit is pulled or cut from the vine with about two inches of stem, and this is very important since by applying a disinfectant to the stem the stem-end rot can be prevented from developing in transit.

Handling.—After the watermelons are pulled and placed in rows in the field they are usually loaded on wagons and hauled direct to market, in the case of local markets, or to cars when they are to be shipped. Most of those shipped are loaded four deep in box cars and in some cases, in cattle cars. The cars are usually cleaned then a layer of clean straw is placed on the floor. The number of melons loaded in a car varies from 800 to 1,500 depending upon the size of the fruits. When the fruits average 35 pounds in weight and are loaded four deep, a car 34 feet long will carry 800. If the average weight is 25 pounds the car loaded in the same way will contain about 1,100 melons.

For express shipments very early in the season watermelons are sometimes packed in barrels, using excelsior, straw or other litter for packing material. This method of packing is used to a very limited extent only.

PUMPKIN AND SQUASH

These two crops are discussed together since the requirements are almost identical, and since some types of the two are distinguished only by experts.

The various types and varieties of squash are of much greater commercial importance than the pumpkin. According to the Bureau of Census the commercial pumpkin crop of 1919 was valued at $137,626, while the squash crop had a value of $685,245. It is probable that some of the so-called pumpkins were really squashes. The two crops together were valued at $822,871 in 1919, and the area of land devoted to their production was 8,426 acres. The leading states in the production of pumpkins were California with 1,132 acres valued at $39,030 and New Jersey with 429 acres valued at $22,550. Massachusetts was in the lead in squash production with 1,052 acres valued at $175,743, and California was second with 942 acres valued at $107,804. While nearly all states produced some squashes none, except the two mentioned, grew over 400 acres.

Origin and Taxonomy.—There is still considerable uncertainty as to the origin of the pumpkin and of the various types of squashes since they are not known in the wild state. Some authorities believe that two of the species *Cucurbita Pepo* and *C. maxima*, are natives of tropical America, while the third, *C. moschata* is believed to be a native of eastern Asia. Others believe that all three species are native of America. It is quite certain that some of the types were grown by the North American Indians before the coming of the white men, since the earliest records refer to pumpkins, or squashes as being grown by the natives along with the corn. Several types grown by the Indians have been described in some of the writings of the explorers and early settlers.

Botanists refer all of the cultivated varieties of pumpkins and squashes to three species, *Cucurbita Pepo*, *C. maxima* and *C. moschata*. All three

of these contain varieties commonly called squash while only one, *C. Pepo*, contains the types generally recognized by botanists and horticulturists as pumpkins. Goff (56) has given the following key to the species:

A. Leaves harsh; calyx tube campanulate, with fleshy or corky segments.
  1. Lobes of leaves rounded, scarcely any sinuses between, peduncles round. *C. maxima.* Squash
  2. Lobes of leaves acute, sinuses between them often deep, peduncles obtusely pentagonal. *C. Pepo.* Pumpkin

B. Leaves soft; calyx tube very short, or scarcely any, segments flat, usually dilated, foliated at apex. *C. moschata.* Pumpkin

Based on the fruits only Goff (56) suggested the following classification:

1. Fruit stem not grooved longitudinally. *Cucurbita maxima.*
   (*a*) Fruits distinctly ringed about the blossom end. American Turban, Bay State, Essex Hybrid and Red China belong here.
   (*b*) Fruits not ringed.
      1. Fruits distinctly oblate. None of the newer, well-known varieties belong in this group.
      2. Fruits roundish, or more or less oblong. Boston Marrow, Hubbard, Warted Hubbard, and Golden Hubbard belong here.
2. Fruit stem distinctly grooved longitudinally.
   A. Fruit stem little expanded at its union with the fruit. *Cucurbita Pepo.*
      (*a*) Fruits with conspicuous projections about the circumference.
         1. Fruits strongly flattened, "pattypan" shaped. White Bush or Patty Pan, and Yellow Bush or Yellow Patty Pan are the best representatives of this group.
         2. Fruits more or less oblong. No well-known variety belongs to this group.
      (*b*) Fruits warty.
         1. Fruits club-shaped, the neck more or less crooked. Summer Crookneck and Giant Crookneck are representatives of this group.
         2. Fruits oval. Brazilian Sugar belongs here, but this is not an important variety.
         3. Fruits roundish or oblate. Common Yellow Field Pumpkin, Sugar and Connecticut Field Pumpkin belong here.
         4. Fruits oval or cylindrical. Italian Vegetable Marrow, Long White Bush Marrow, Mammoth Pumpkin and Vegetable Marrow belong in this group.
   B. Fruit stem broadly expanded at its union with the fruit. *Cucurbita moschata.*
      (*a*) Fruit club-shaped or pyriform, the neck usually more or less crooked. Canada Crookneck, Cushaw (Cashaw), Winter Crookneck and Japanese Crookneck belong here.
      (*b*) Fruits oblong. Early Neapolitan belongs here, but it is not a well-known variety.
      (*c*) Fruits distinctly oblate. Large Cheese is the best known variety in this group. This is usually called "Large Cheese Pumpkin."

It is of interest to note that *Cucurbita Pepo* contains both the bush and running varieties of summer squashes and also the running varieties known as pumpkins. These two types are very distinct in general appearance and in growth of vine, and for this reason some authorities have suggested separating them into botanical varieties. It is very confusing to call one type squash and another type in the same species pumpkins, but to call all varieties pumpkins, as is done in Europe, affords no means of distinguishing the groups except through varietal names.

Culture.—The general requirements of the pumpkin and of the squash are not very different from the other cucurbits. These crops do not require as long a growing season as the watermelon and muskmelon and for this reason they can be and are grown in nearly all parts of the United States and in many of the provinces of Canada. While the plants are not as tender as melon plants they are injured by frost, so that planting should be delayed until the weather has settled and the ground has become warm.

Any good type of well-drained soil will produce satisfactory crops of pumpkins and squashes if other conditions are favorable. They are often grown on heavier soil than is considered safe for melons in the North. Summer squashes grown for market, are usually produced on sandy loam soils in order to have them ready for sale as early as possible.

In many sections pumpkins are grown as a companion crop to corn. When so grown they require no cultivation and care except that given the corn.

The time and method of planting squashes and pumpkins are about the same as for the other cucurbits. They are sometimes started in hotbeds and greenhouses, but this is not a common practice. Bush squashes are planted in hills about 4 by 4 or 4 by 5 feet or in rows 4 to 5 feet apart. In the latter method the seeds are sown thickly and the plants thinned to stand about three feet apart in the row. The running varieties of squashes and pumpkins are planted either in hills, or in drills. When planted in hills the spacing varies from 8 by 8 to 10 by 12 feet depending upon the fertility of the soil and the vigor of the varieties. In the drill method the seeds are sown in the row and the plants thinned to stand 3 to 4 feet apart in the row.

The same cultivation and care are suggested as for the other cucurbits.

Varieties.—There are two general types of cucurbits known under the term squash, namely summer squash, belonging to *Cucurbita Pepo* and the autumn or winter squashes including the two species *C. maxima* and *C. moschata.* Summer squashes include the scalloped type as represented by the White Bush or Patty Pan, and the Yellow Bush, and by the crooknecked type including the Summer Crookneck and Giant Crookneck. In some regions, especially in the South, the summer

squashes are known as cymlings or cymblings. The important autumn and winter squashes belonging to *C. maxima* are Hubbard, Warted Hubbard, Golden Hubbard, Delicious, and Boston Marrow. This is the most important group of varieties produced in the North. The best known varieties belonging to *C. moschata* are Canada Crookneck, Japanese Crookneck, Large Cheese, Dunkard, and two or three strains or varieties known as Cushaw. These are often called pumpkins, but since they are quite distinct from the large-fruited late varieties belonging to *C. Pepo* it seems best to list these as squashes. The Cushaw is considered a desirable type for the South. The best known varieties of pumpkins (*C. Pepo*) are Small Sugar (also called Sweet or Sugar), Common Yellow Field and Connecticut Field.

Improvement of the Hubbard Squash.—The Hubbard squash is the most important variety and considerable attention has been given to its improvement. Cummings (34) has made a careful and exhaustive study of inheritance of yield and quality in this variety. He has found that great variation exists in both yield and quality. Some of his conclusions, after years of investigation, are as follows:

The immediate effect of self-pollination was found to be negligible. Inter-crossing was without apparent effect on yield. In both cases the progeny, which were the products of selections from high- and low-yielding strains, were segregated and maintained with good contrasts as to yields, entirely independent of the method of pollination. Neither self-pollination nor inter-crossing were influential in controlling yield; but seed selection was effective.

Hubbards vary much in quality. Some are wet, lumpy, stringy and insipid, while others are dry, mealy, sweet and delectable; and there are all gradations between these extremes, and many different combinations of quality factors. Such characters are associated in part with season, soil and maturity, and in part with the breed and its purity of quality. Quality is a generic word and embraces several different things, such as flavor, texture, fibrination and amount of moisture. It is partly a matter of physical characteristics and partly a matter of proportional chemical composition. . . .

Edibility tests, substantiated by chemical analyses, show that specimens of good quality contain more carbohydrates and less water and crude protein than do those of poor quality. In general, the physical analyses and edibility tests indicate what the chemical analysis reveals, namely: Differences in the amount of water, crude protein and carbohydrates as between different squashes.

Four separate strains—two good, and two poor—were isolated and grown for several years. Meanwhile, edibility tests have shown that it is possible to project either good or poor quality to succeeding generations under conditions of experimental control. Within certain limits, good squash give rise to good quality progeny and poor squash to poor quality progeny.

A large percentage of the offspring resemble the parent in quality. However, once good quality is secured constant care in seed selection and in flower

manipulation are necessary in order to avoid cross-pollination and to maintain good quality.

"Excellent" quality is generally associated with full maturity and ripeness, a hard, thick shell and clear color demarcation between flesh and shell. Excellent specimens have a relatively small number of seeds, not more than two-thirds as many as the poor ones. Large size is not necessarily or usually associated with superior quality, but full maturity is imperative.

It seems clear that one may propagate almost at will either a strain of poor quality or a strain of good quality, and that the characteristics of the parent squash and its immediate ancestry in the main determine the grade of the progeny. Most commercial seed stock is protean in nature and quality; but by means of self-fertilization and seed selection good quality can be promptly isolated and a desirable strain established.

Diseases.—Pumpkins and squashes ordinarily are not seriously injured by disease, although they are attacked by downy mildew, bacterial wilt and anthracnose. For a discussion of the first two see "cucumber," and for anthracnose see "watermelon."

Insects.—The most important insect pests of these crops are the squash bug and the squash vine borer. Both of these seem to prefer the pumpkin and squash vines to the other cucurbits and are often very destructive. Some of the other insects discussed under cucumber also attack these crops. See discussion of insects under cucumber.

Harvesting.—Bush squashes are harvested as soon as the fruits are of edible size and before the rind begins to harden. The simplest test to determine when the summer squash is too old is the use of the thumb nail. When the rind becomes somewhat resistant to the pressure of the thumb nail it is too old to be used for food and should not be marketed. This test is of no value for the other types of squashes. In fact, the harder and more resistant the rind of the maxima and moschata squashes the better, but since these are seldom used before they are thoroughly mature no test is usually necessary. High quality of winter squashes is generally associated with maturity, so that they should not be harvested until they are fully ripe, but before they have been frosted.

Both pumpkins and squashes are pulled or cut from the vine with a portion of the stem attached to the fruit. This is desirable since the removal of the stem would leave a large scar through which decay organisms could easily enter.

Careful handling from the time they are harvested until they are finally disposed of is important since fruits bruised or otherwise injured decay much more rapidly than uninjured ones. Any breaking of the skin is usually followed by decay.

Storage.—Squashes and pumpkins can be kept for several months if they are in good condition at the time of storage and are kept at the proper temperature and humidity. The conditions necessary to keep

these crops are very different from those necessary to keep root crops. Stuart (152) gives the following points as necessary to insure minimum loss of squash in storage:

1. The squashes should be well matured.
2. They should be cut or carefully broken from the vine, leaving the stem attached to the squash.
3. They should be placed in small piles to ripen before hauling from the field.
4. They should be hauled in a spring-wagon box lined with burlap or other material.
5. The storage room should be dry and moderately warm, at least for first two weeks to harden up the shells after which a lower temperature may be maintained.
6. From harvest to sale they should be handled as one would handle eggs. Broken stems and bruised skin are sure to cause decay.

Most authorities agree that pumpkins and squashes should be kept at a relatively high temperature, preferably between 50 and 60 degrees F. For a small supply the fruits may be stored on shelves near the furnace, but for large quantities special storage houses are desirable. The house should be well built, thoroughly insulated and provided with good ventilation and some means of heating. The inside of the house is fitted with racks or shelves made of 1 by 3 or 1 by 4 inch slats, placed 2 to 3 inches apart to allow a free circulation of air. It is considered best to place only one layer of fruits on a shelf as piling them one on top of another causes slight bruising. However, they are sometimes piled three or four fruits deep on the shelves.

Stuart (152) has reported the results of a storage test with Hubbard Squash stored in a dry and medium warm room (50 to 60 degrees). One ton was stored on October 3 and on December 4 the squashes weighed 1,810 pounds, on January 6, 1,657 pounds, February 3, four months after harvesting, the sound fruit weighed 1,488 pounds. The total moisture loss was 20.8 per cent and the loss by decay was 4.8 per cent or a total loss of 25.6 per cent. At the time of storage the wholesale price was one cent per pound, late in December 2.5 to 3 cents and at the end of the experiment the 1,488 pounds sold for $53. This difference in price is more than can be depended upon in most years, but the value during the winter is usually enough greater than in the fall to give a good profit for storage, provided the losses are not excessive.

CHAPTER XXVII

SWEET CORN, OKRA, MARTYNIA

These three crops are placed together because none of them fit into the other groups, and not on account of any special similarity. They are, however, all warm season annuals, are tender to frost and are grown for their fruits. Only one, sweet corn, is of any great commercial importance in the United States. Sweet corn is of greatest importance in the North; okra is produced mainly in the South; and martynia is grown to a limited extent only, largely as a curiosity.

SWEET CORN

While the sweet corn plant is tender to frost and grows best in hot weather, the main areas of commercial production in the United States are in the northern states. The crop is also grown in portions of Canada. It is not an important commercial crop in any state south of Maryland. This is due probably to the serious injury done by the corn earworm in the South, and to high temperatures at harvest time. At high temperatures the corn matures very rapidly and it is difficult to harvest the ears at just the right time and if this is not done a loss results. After the ears are pulled from the stalk there is a rapid deterioration in quality due to the loss of sugar and the higher the temperature the more rapid the change. These factors give the cooler regions a decided advantage over the South in sweet corn production.

Sweet corn production is not limited by climatic conditions to the same extent as is field corn for grain since the former is harvested for use before it begins to harden. Sweet corn is a very successful crop in many regions of the North where field corn for grain cannot be produced in normal seasons.

Sweet corn is shipped to a very limited extent only, because of the rapid deterioration in quality, hence most of the crop consumed in the fresh state is produced in the home garden, and in market gardens. A very large percentage of the crop is grown for canning.

Statistics of Production.—Sweet corn in 1919 ranked sixth in value among the vegetables, being exceeded by Irish potatoes, sweet potatoes, cabbage, onions and tomatoes. In that year 271,584 acres of land were devoted to sweet corn for sale and the value of the crop was $17,297, 561. Six states, Maryland, New York, Iowa, Ohio, Illinois and Pennsylvania

produced about 60 per cent of the entire crop. Table LXV gives the production for the United States and for the ten leading states.

TABLE LXV.—ACREAGE, VALUE OF PRODUCT AND AVERAGE VALUE PER ACRE OF SWEET CORN GROWN IN THE TEN LEADING STATES AND THE TOTALS FOR THE UNITED STATES

State	Farms reporting	Acres harvested	Value of product	Average value per acre
Maryland	5,924	34,778	$ 1,766,229	$ 51
New York	10,681	28,965	2,028,617	70
Iowa	4,494	28,595	1,012,771	35
Ohio	9,712	27,902	1,590,479	57
Illinois	4,263	26,643	1,055,497	40
Pennsylvania	17,171	22,255	1,751,533	79
New Jersey	4,624	15,572	1,317,821	85
Maine	6,712	11,316	1,554,800	137
Indiana	3,066	10,101	488,257	48
Michigan	4,999	9,944	483,479	49
United States	103,784	271,584	17,297,561	64

Examination of the table will show that the average value per acre in New York, Pennsylvania, New Jersey and Maine was much greater than in the other states. This is due partly to the fact that a larger portion of the crop was sold as green corn in the former group of states than in the latter group, and in part to the higher price paid by the canners in the East. A much larger part of the crop grown in Maryland goes to the canning factories than in the other eastern states.

Influence of Climate.—Reference has been made to the effect of hot weather on the rapid maturity of sweet corn and also on the injury caused by the corn ear worm. There has been a widespread belief that sweet corn canned near the northern limit of its production is sweeter and of better quality than that canned farther south. Experimental evidence shows quite conclusively that this is true, but the belief that sweet corn develops a higher sugar content in the North than in the South is not borne out by experimental data. Straughn (148) has reported analyses of sweet corn grown at Clemson College, South Carolina; College Park, Maryland; New Brunswick, New Jersey; New Haven, Connecticut and Orono, Maine. The data reported represent from 20 to 100 analyses of each variety at each station. The highest percentage of sugar in both the Crosby and Stowell's Evergreen was in the corn grown in South Carolina, and the lowest in Connecticut.

Later Straughn and Church (149) reported on results secured during 4 years, 1905 to 1908, for the Crosby and Stowell's Evergreen varieties grown in Florida, South Carolina, Maryland, Connecticut and Maine. In this work the seed used at all of the stations was the same strain and the analyses were made at the stations where the corn was grown. Their results failed to show any direct relation between latitude in which the corn was grown and the sugar content. Three years out of four the corn grown in South Carolina had the highest sugar content and in the other year there was very little difference between the three highest. Connecticut-grown corn had the lowest percentage of sugar, while that from Maine and Maryland was intermediate and about equal.

The advantages of northern canned corn are apparently not due to the difference in sugar content at time of harvest, but rather to the temperature prevailing at harvest time. Appleman and Arthur (3) have shown that the temperature to which the corn is subjected after being pulled from the stalk influences the rate of sugar loss, the higher the temperature the more rapid the loss. (See Harvesting.) Stevens and Higgins (142) have shown that the temperature prevailing during harvest time in Maryland is considerably higher than that which prevails in Maine. They state that corn canning in Maryland falls largely in August, while in Maine it is mainly in September. The mean temperature for Baltimore, Maryland, from August 2 to 31 is 74.6 degrees F. and at Portland, Maine, the mean temperature for September is 59.5. The bulk of the corn canned in Maryland is harvested in August and a large part of the Maine corn is harvested in September. The highest mean temperature at Portland, Maine, 62.6 degrees F. is 6 degrees below the lowest mean for Baltimore, 68.6 degrees.

History and Taxonomy.—Sweet corn is probably of very recent origin, since it was not mentioned by Jefferson in his *Notes on Virginia*, 1781, nor by McMahon, 1806. A writer in the New England Farmer, August 3, 1822, states that sweet corn was not known in New England until a gentleman from Plymouth, who was in General Sullivan's expedition against the Indians in 1779 brought back a few ears which he found among the Indians on the border of the Susquehanna. Another writer in September, 1822, asserts that this sweet corn was brought back by Lieutenant Richard Bagnal from General Sullivan's expedition against the Six Nations in 1779 and was called *papoon corn*. In 1832 sweet corn was mentioned by Bridgeman (Gard. Asst. 1832). After about 1850 it was frequently mentioned by writers, Buist in 1851, mentions two varieties (Family Kitchen Garden 61.1851) and in 1854 Schenck mentions three varieties as having been brought into notice within a few months. In 1866 Burr describes 12 varieties.

The word *corn* has a special meaning in the United States and is applied only to Indian corn or maize while in other countries it applies to

all bread grains. In Europe the word "corn" applies to oats, wheat, rye or barley, as well as to Indian corn. The references to corn in the Bible probably refer only to the small grains since Indian corn or maize was not known in the Eastern Hemisphere prior to the discovery of America.

Corn or Indian corn was probably grown by the natives of the Americas from a very ancient date. Plumb (117) writes that "mounds that were erected prior to the time of the American Indian, of which he has no tradition, that have been explored in recent years, have contained corn cobs and charred kernels. In the caves, occupied by the early Cliff dwellers in the southwestern states ears of corn have frequently been discovered. In South America, Darwin found on the coast of Peru heads of maize, together with eighteen species of recent sea-shells embedded in a beach which had been upraised at least 85 feet above the level of the sea. Ears of Indian corn are occasionally found in vessels placed in ancient Indian tombs or mounds in Chili, Peru and Central America."

The early explorers of this country found the Indians growing corn from Canada to Florida. They taught the early settlers how to grow it. In fact, it was the leading crop among the natives of this continent at the time of the discovery of America.

Authorities generally agree that corn is probably a native of Mexico. Harshberger (61) states that "all plants closely related to maize are Mexican. The evidence to the present date (1893) places the original home of our American cereal maize in Central Mexico."

Sweet corn and field corn belong to the grass family and to the genus *Zea*. These two are considered by most authorities as belonging to the same species, *Zea Mays* Linn. and sweet corn is designated by the variety name *rugosa*. Bailey ("Cyclo. Amer. Hort." 2006, 1902) suggested *Zea Mays* var. *Saccharata* and Sturtevant (3rd Rep. N. Y. Expt. Sta. 1884) listed sweet corn as *Zea saccharata*. Sweet corn is distinguished from other corns by its high sugar content when in the milk and early dough stage and by its wrinkled, translucent kernels when dry.

Soil Preference.—Sweet corn, like field corn, can be grown on a great variety of soils. Where earliness is an important factor, as in the production of early corn for a local market, a well-drained sandy loam soil is considered best since such a soil warms up early in the spring and usually matures a crop before drought occurs. Such a soil, if supplied with humus and is well fertilized, will produce a good yield even during the drier part of the season. In growing sweet corn for the canning factory a large yield is more important than earliness, therefore, a rich, retentive soil is desired. Silts, silt loams, and clay loams are better than the sandy and sandy loam soils for the canning crop. In many regions, as in the Genessee Valley of New York and the Scioto Valley of Ohio, rich river bottom lands are used quite extensively for sweet corn production. These soils are not

only rich in mineral nutrients, but are less subject to drought than most other soils. Such soils are enriched by the deposit of sediment during periods of flood. Muck soil has been used to advantage in the production of sweet corn. Frost usually occurs later in spring and earlier in fall on these soils than on the surrounding uplands, but in nearly all regions where field corn can be grown for grain on upland soils the growing season on the muck is long enough to produce a crop of sweet corn. These soils in the upper part of the corn belt, are not satisfactory for field corn for grain on account of the late frosts in spring and early frosts in fall.

Manures and Fertilizers.—While sweet corn is a heavy feeder it is not a common practice to fertilize very heavily, except in growing early corn for market on the lighter soils. Under such conditions 1,000 to 1,500 pounds of a high-grade complete fertilizer is often applied, and manure is sometimes used in addition. Where manure is used at the rate of 10 to 15 tons to the acre a light application of nitrate of soda to give the plants a quick start and 400 to 500 pounds of acid phosphate should give large yields if other factors are favorable. When corn is grown for the canning factory a light application of manure and 200 to 400 pounds of acid phosphate are often applied. On the richer alluvial soils many growers apply no fertilizer, but a light application of acid phosphate or other phosphorus carrier would usually be advisable. On most upland soils, if manure is not used, it is necessary to turn under green manure or other material to keep up the humus supply. It is possible to grow profitable crops with commercial fertilizers and green manures, but not with the fertilizers alone unless the soil is already supplied with vegetable matter.

Results of fertilizer experiments on sweet corn reported by Thorne (163) indicate that production can be maintained by the use of commercial fertilizers in conjunction with green-manure crops. These results were secured on a run-down alluvial soil, and cover a period of 5 years, 1915 to 1919. The yield records show that phosphorus was more important than either nitrogen or potash. The average yield was as large from 400 pounds of acid phosphate alone as from 16 tons of manure plus 400 pounds acid phosphate. The complete summary of these results is given in Chapter III.

Difference of opinion exists as to whether it is better to apply the fertilizer in the hill or to apply it broadcast. Some writers have asserted that when the fertilizer is applied in the hill corn suffers more from drought than when the fertilizer is broadcasted. This has been explained as being due to a smaller root system where hill application is practiced. There is no evidence that the location of the fertilizer in the hill has any tendency to restrict the root system. Millar (96) has reported results of experiments with corn in Michigan in which a comparison of hill and broadcast applications was made. The soil on which this experiment was conducted is a dark sandy loam resting on a heavy clay subsoil.

The hills were placed 44 inches apart each way and the variety of corn was Golden Glow. A complete fertilizer having the composition 3–10–4 was used, and the hill application was at the rate of 200 pounds to the acre. This was sprinkled over an area about 8 inches long and 4 to 5 inches wide in the bottom of the hill and covered with about one-half inch of soil before dropping the seed. For comparison 400 pounds of the same fertilizer were applied broadcast on one portion of the field and this was mixed with soil before the corn was planted. At the end of 30 days the corn fertilized with 200 pounds of the mixture applied in the hill was much larger than that on the broadcast treatment. The root systems were dug out in order to show the effect of the method of fertilizer application on the extent of the root growth. The author states that there was little, if any, difference in the extent of the root growth and that the application of the fertilizer under the seed did not lead to a centralization of roots in this zone. A second examination was made 57 days after planting and at this time the corn fertilized in the hill was in full tassel and in the early silk stage while that fertilized broadcast was just coming into tassel. The root systems were well distributed throughout the soil in both cases. Commenting on these results Millar has the following to say:

> The results of this experiment show no striking variation in root development of corn as a result of the two methods of fertilizer distribution employed. It would seem, therefore, that the observations of some farmers to the effect that corn fertilized in the hill sometimes suffers more from drought than unfertilized corn is not due to a more limited root system. It would seem probable that when such a condition prevails the reason lies in a greater moisture requirement of the plants, due to a greater vegetative growth.
>
> Applying fertilizer under the hill as was done in this experiment, is doubtless more stimulating to the plant than applying above the seed, as is done by most planters. The difference should be more pronounced during seasons of light rainfall. It seems probable, therefore, that the greater rate of growth and earlier maturity resulting from hill fertilization in this experiment would not always be noted under average farm conditions.

The results quoted did not show the effect of the method of application on total yield. It would seem that in an average season the yield would be larger from the heavier application of fertilizer if the soil needed as much as 400 pounds of the mixture used. Since the roots of the corn plant reach all parts of the soil to a considerable depth the fertilizer would be within reach of the roots and eventually would be utilized even under broadcast application. The advantage of the hill application is probably in giving the plant a good start before the roots have much of a spread.

In general it may be said that applications of 500 pounds or more to the acre should be applied broadcast, or part broadcast and part in the

hill. There is danger of injuring the plant roots with a heavy application of fertilizer in the hill. Applications of 200 or 300 pounds to the acre may give better results if applied in the hill rather than broadcast, but this would probably depend somewhat on the character of the soil and the amount of rainfall.

Planting.—Sweet corn is injured by frost hence it is not safe to plant until the danger of hard frosts is over. It is worth while, however, to take chances on frosts where the crop is grown for a local market in which early corn brings high prices. As a rule it is safe to plant sweet corn about the time of the last killing frost in spring. In order to have sweet corn available from the time the earliest varieties are ready for use until frost in autumn it is necessary to make several plantings, or else to plant early, medium and late varieties at about the same time. One practice is to make a planting of an early variety as early in the spring as the conditions will allow. In 2 or 3 weeks another planting is made of the same or a similar variety and at the same time a medium and a late variety are planted. Another practice is to make several plantings of one variety, usually an early one at intervals of 2 or 3 weeks, the last planting being made at such a time that it will be ready for use just before frost in the autumn. The time that this last planting should be made depends upon the variety used and the locality.

For a very early crop the plants may be started in the greenhouse or hotbed 3 or 4 weeks before time for planting in the field. Seeds are planted in plant bands, pots, or other receptacles, several seeds to each receptacle. In setting the plants in the field or garden care must be taken not to disturb the roots. After the plants have become established they are thinned to the desired number in each hill. This method of growing plants is practicable only for home use and for a special market. The planting distance for sweet corn depends upon the variety grown, since the larger the variety the more space required. Both drill and hill method of planting are practiced and there exists considerable difference of opinion as to which is the better. With the hill method, cultivation can be given in both directions and this reduces the amount of hand work required. On the other hand, the drill method gives a better distribution of plants and very often a larger yield. When the hill method is employed 6 to 8 seeds are planted and the plants are thinned to 3 or 4 to the hill. The hills are spaced 2 by 2½ or 2 by 3 feet apart for the small-growing varieties and 2½ by 3, 3 by 3 or 3½ by 3½ feet for the large growing varieties. In the drill method the seeds are distributed singly and the plants are thinned to stand 10 to 15 inches apart in the row, the distance depending largely upon the variety.

Planting is done either by hand or by means of a horse-drawn planter. When planted by hand the kernels may be dropped into a shallow furrow, or a hand planter may be used. The hand planter is a great labor saver

and is used quite largely by market gardeners in many regions. Machine planters are made to plant either one or two rows at a time. These machines open the furrow, drop the corn and cover it all at one operation. For small acreages the large machines are not justified, but for large acreages they may be economical.

The amount of seed required to plant an acre depends upon the distances and rate of planting, and upon the size of the kernels. In general the amount ranges from 10 to 20 pounds per acre.

Cultivation.—The cultivation of sweet corn is about the same as that given field corn. Many growers follow the practice of running a weeder, or a spike-tooth harrow over the field before the corn comes up, and sometimes after it is up. This is a good practice as the breaking of the surface destroys the weeds and gives the corn a chance to get started ahead of them. Even after the corn comes up the weeder or harrow can be used to good advantage as the surface is loosened and the weeds destroyed between the plants in the row as well as between the rows, whereas with a cultivator only the space between the rows is cultivated. The use of the weeder or harrow eliminates some of the hand work. After the plants are 3 to 4 inches high a cultivator is used in place of the weeder and the cultivation is confined to the space between the rows. Both one-horse and two-horse cultivators are used, the former on small areas and the latter where sweet corn is grown on a large scale. Most of the growers for canning factories in New York use a two-horse cultivator.

Some authorities advocate deep cultivation while the plants are small and shallow cultivation later when the roots extend a considerable distance from the plants. If, however, the land has been well prepared there is no point to deep cultivation at any time, and the turning up of the moist soil increases the water loss by evaporation. Thorough preparation of the seed bed and shallow cultivation make a good combination. Only shallow cultivation should be given after the roots extend across the rows for deep cultivation results in destruction of many roots.

Results of experiments in the cultivation of field corn, carried on by many experiment stations and by the U. S. Department of Agriculture have shown conclusively that destruction of weeds is the main object to be accomplished in cultivation. Cates and Cox (22) have reported on a series of cooperative experiments carried on in 28 states and covering a five-year period, 1907 to 1912. In all, 124 experiments were conducted and the average yield of the uncultivated plats was 99.108 per cent of the yield from the cultivated ones. In the uncultivated plats the weeds were kept down by cutting them off at the surface of the soil without forming a mulch. They found no correlation between the rainfall and the comparative values of cultivation and no cultivation.

Mosier and Gustafson (101) grouped the experiments of Cates and Cox according to soil type and found a slight correlation. On clay

soils the average yields of the uncultivated plats was 92.6 per cent of that of the cultivated ones, clay loams 94.5 per cent, silt loams 102.4 and sandy soils 105.7 per cent.

Results of cultivation experiments with corn carried on by the Illinois Experiment Station for a period of 9 years have been reported by Mosier and Gustafson (101). The average yield of corn was 39.2 bushels on plats cultivated three times; 45.9 bushels where no cultivation was given, but where weeds were kept down by scraping; and 7.3 bushels per acre on plats where the weeds were allowed to grow. These investigators showed that the injurious effects of the weeds were due to some factor or factors other than the depletion of moisture, since parts of the weed plats were irrigated and the yield was increased only 3 bushels per acre over no irrigation.

Many other experiments on corn cultivation have been conducted, but since most of them have given the same general results as those mentioned they are not reported here. A few have shown considerable gain for cultivation over scraping to keep down weeds, but by far the greater number have shown little or no gain, and, in many cases, a loss for cultivation.

In general the experimental results justify the conclusion that the primary object of cultivation is the destruction of weeds and not the conservation of moisture by a dust mulch. There is some evidence that on heavy soils there is slight benefit from cultivation other than weed control. This benefit may be ascribed to better aeration, due to the breaking up of the hard crust, but the evidence on this point is not conclusive. (See Chapter X.)

Suckering.—The removal of suckers from the base of the corn plant is a very old practice and was formerly followed to a greater extent than it is today. In fact, it has been largely discontinued in field corn culture and is not followed by a large percentage of sweet corn growers, although it is almost the universal practice in some localities as in Nassau County, New York. The advantages claimed for the practice are increased yield, larger size and earlier maturity. Various writers have explained that removal of the suckers increase the yield because the raw materials brought into the plant from the soil would go to the ear instead of to the suckers. In this explanation the fact that the materials brought into the plant from the soil are not foods until they have undergone manufacture in the foliage is overlooked. The suckers themselves aid in this manufacture. These writers have tried to explain something that has not been proved, and which probably is not generally true.

Experiments conducted by the writer at Ithaca, New York, covering a period of 3 years seem to show that removal of the suckers decreases the yield and does not increase earliness, nor appreciably increase the size of the ears. In these experiments the Golden Bantam and Stowell's

Evergreen varieties were used and there were seven replications each year, except the first when there were only four. The treatments were as follows:

1. Check—suckers allowed to grow.
2. Suckers removed once when the plants were 12 to 18 inches high.
3. Suckers removed when the plants were 12 to 18 inches high and at intervals of a week or ten days as long as any started.
4. Suckers removed when plants were in tassel.

The rows were 150 feet long and spaced 3 feet apart. The corn was planted in hills, 2 feet apart for Golden Bantam and 3 feet for Stowell's Evergreen. The plants were thinned to three to each hill.

Table LXVI gives the average yield of the two varieties under the different treatments for the two years 1920 and 1921. The data for 1919 are not included because only the Golden Bantam variety was used that year and one of the treatments was left out. The results were practically the same for the three treatments tested in 1919 as for the same ones used in the other two years. The figures given include only marketable ears.

TABLE LXVI.—AVERAGE YIELD OF SWEET CORN IN SUCKERING EXPERIMENT' ITHACA, NEW YORK, 1920 AND 1921

Treatment	Golden Bantam				Stowell's Evergreen			
	Total yield		Yield Grade 1		Total yield		Yield Grade 1	
	No. ears	Weight, lb.	No. ears	Weight, lb.	No. ears	Weight, lb.	No. ears	Weight, lb.
1	1,300.5	454.0	950.0	368.5	754.0	567.7	598.5	487.5
2	1,219.0	423.0	903.0	348.0	727.5	550.0	593.0	480.9
3	1,143.0	412.5	883.5	346.5	730.0	557.0	606.0	488.5
4	1,145.0	405.0	854.5	332.5	717.0	538.5	587.0	469.5

A study of Table LXVI will show that the plants not suckered produced the highest total yield in both number of ears and weight for both varieties. The later the suckers were removed the greater the reduction in yield. This is as would be expected since the larger the sucker at time of removal the more the balance between the roots and stalks would be upset and also the greater the reduction of the manufacturing area of the plant.

There was a slight advantage in earliness for early suckering with Golden Bantam. The average yield of the check for the first picking was 390 ears weighing 143 pounds, for the plants suckered early 402 ears weighing 147 pounds, for the third method 382 ears 144 pounds, and the fourth method 349 ears weighing 130 pounds.

Results of cooperative experiments on three farms in New Jersey reported by De Baun (N. J. *Rept.* 1915), show the same order of yields as those given in Table LXVI. The New Jersey tests were conducted for only one season, a favorable one for sweet corn. The name of the variety used was not given in the report.

An experiment conducted at the New Hampshire Station in 1921 (N. H. *Bull.* 203) shows a slight loss (5.8 per cent) for suckering of early Crosby and a slight gain (2.6 per cent) for suckering of Golden Bantam. The size of the ears was the same for suckered and unsuckered plants of both varieties.

Sweet corn suckering experiments have not been carried on long enough and have not covered a sufficiently wide range of soil and climatic conditions to show conclusively the effects of the practice. The experimental evidence available, and the fact that most growers have discontinued the practice, would seem to justify the statement that under most conditions suckering is not advisable. The expense is certainly not justified in the growing of corn for the canning factory.

Varieties.—Varieties of sweet corn are usually grouped into three classes or groups, early, medium and late. These terms are somewhat confusing since the so-called early varieties are often planted late in the season, much later than the so-called late varieties. The terms refer to the length of time required to produce edible ears, and when varieties of these three classes are planted at the same time in the spring "early," "medium" and "late" characterize them with reference to time of edible maturity. However, there is some overlapping.

The following characterization of the important varieties is given to indicate the general characteristics and not for purposes of identification:

Adams Early.—This is not a true sweet corn, but a variety of field corn which is grown for use in the green state. It is early, and more hardy than most varieties of sweet corn. The plant is of medium size (6 to 8 feet tall); ears 8 to 10 inches long; grains white; husk thick. This variety is not of high quality, but is grown to some extent because it is hardy and may be planted early. The thick husk may be of some advantage in the South where the corn ear worm is a serious enemy of sweet corn.

Mayflower (Early Mayflower).—This is an early variety of sweet corn very popular in some sections of the East. It is a small-growing variety with small ears, 5 to 6 inches long; grains white; quality fair to good for a very early variety.

Early Minnesota.—A standard early variety, fairly rank grower; ears small in size, 5 to 7 inches long; grains white; quality good.

White Cob Cory.—This is one of the earliest varieties, and is very popular in many sections. The plants are small, 4 to 5 feet high; ears small, containing 8 rows of white kernels.

Red Cob Cory.—This is similar to the preceding variety in general characters except that it has a red cob.

Golden Bantam.—This is the best known of the yellow varieties of sweet corn and is one of the parents of most of the others. During the past few years the Golden Bantam and other yellow varieties have become very popular. In some regions this is by far the most important early variety. The plants are small and sucker freely; ears small, 5 to 6 inches long, 8-rowed; grains large, rich yellow color; quality good. It is not as early as some of the white varieties.

Crosby.—This is a second-early or midseason variety and one of the old standbys. The plant is small; ears 5 to 7 inches long, with 10 or 12 rows of white kernels; quality good.

Metropolitan.—This is a small-growing, second-early variety, with medium to large ears (8 to 9 inches long); 10 to 12 rows of white kernels; quality good.

Kendel's Early Giant.—A second-early variety, producing large ears, with 10 to 12 or more rows of white kernels; quality good.

Howling Mob.—This is a small-growing, midseason variety, producing medium to large ears with 12 to 14 rows of white kernels. In some sections of the East this is the most important market variety. It is prolific and of very good quality.

Black Mexican.—This is a medium-growing, second-early or midseason variety. The ears are medium in size, containing 8 to 10 rows of kernels. The kernels turn to purple and black in color and for this reason it is not a popular market variety. It is of high quality and is grown to some extent for home use.

Golden Giant.—This is a second-early or midseason variety, and is said to be a cross between Golden Bantam and Howling Mob. The ears are larger than Golden Bantam, but have the same color and much the same flavor.

Other Midseason Yellow Varieties.—There are many so-called midseason varieties of yellow sweet corn, including Butter Cup, Semour's Sweet Orange, Whipple's New Yellow and Golden Rod. All of these are larger than Golden Bantam and are becoming popular on the market. They are very similar in general appearance and in quality.

Stowell's Evergreen.—This is one of the old varieties and is still the leading late corn for market and the most important canning variety. It is a rank grower and produces large ears with 12 to 20 rows of kernels. The kernels are white, deep, and of fine flavor.

Country Gentleman.—The stalk and ears of this variety are of medium size. The grains are small, deep, white in color, and irregularly arranged. This is considered a good variety for market and also for canning. The irregular rows and the lack of space between the rows make it somewhat objectionable for serving on the cob.

Long Island Beauty.—A large-growing, late variety, with large ears, very popular on Long Island. The kernels are small and are arranged in 12 to 18 rows. The quality is fair, not as good as Stowell's Evergreen and many of the other varieties.

Bantam Evergreen.—This variety is a cross between Golden Bantam and Stowell's Evergreen. The stalks are medium to large in size and the ears are large and contain 14 to 18 rows of medium-sized kernels of a yellow color. The quality is good and the variety is a heavy yielder. This is a popular late variety of yellow sweet corn.

Golden Cream.—This is said to be a cross between Golden Bantam and Country Gentleman, combining the color and flavor of the former with the size of the latter. It is a late variety, but not quite so late as Country Gentleman. The color is light yellow; quality good.

Insects.—Several insects attack sweet corn and under some conditions severe injury is done. The most destructive insects are the corn ear worm, European corn borer, southern corn rootworm, cutworms, white grubs and wireworms. The last three are discussed in Chapter XIII.

Corn Earworm.—The corn earworm is a very serious pest of sweet corn in the South and in many sections of the North, but is usually not present in injurious numbers in the northern part of the sweet corn belt. This insect is the same as the bollworm of cotton and the fruitworm of tomato. It is also called the tobacco budworm, and it attacks pumpkins, squashes, melons, peppers and other vegetables. The worm in the larval stage of a moth (*Heliothis obsoleta*) and when full grown is 1½ to 2 inches long, and varying in color from light green to brown. The eggs are laid on the silk and the larvae work their way down under the husk where they feed on the silk and unripe kernels. Even where the insects do not eat very much of the corn the injury is serious because of the entrance of rain through the opening made by the worm and this is followed by decay.

No thoroughly satisfactory and practicable control measure has been found for this insect although dusting the silk with arsenate of lead powder has greatly reduced the injury. A mixture of 50 per cent arsenate of lead powder and 50 per cent ground sulphur proved quite successful in experiments in New Jersey. This treatment has not been used to any great extent in commercial plantings.

Crop rotation is of little value, as the insect feeds upon many kinds of plants, including grasses and clovers.

European Corn Borer (*Pyraüsta nubilalis*).—This pest was recently introduced from Europe and is now found in New England, New York, northwestern Pennsylvania, Ontario, northern Ohio and southern Michigan, including all counties bordering on Lake Erie. The larva is about three-fourths of an inch long, yellowish-gray in color with faint reddish or brownish stripes. The caterpillars bore into all parts of the plant except the root and cause great damage when they are present in

considerable numbers. The breaking over of the tassels due to the feeding of the caterpillars, the sawdust-like borings on the stalks in midsummer, and later the breaking over of the stalk just above the ear are characteristics by which the presence of the insect may be detected.

This insect feeds upon a great many plants including many vegetables and flowers, field corn, sorghums, millets and a large number of weeds. This makes control very difficult if not impossible. To reduce the danger of serious damage and rapid spread of the insect to new territory Cotton (30) suggests the adoption of the following precautions:

1. Cut corn close to the ground as early as practicable.
2. Place as large a part of the crop in the silo as is possible. This should include all waste from canning factories. The fermentation destroys the borers.
3. Cut or shred cornstalks before feeding same; this kills many of the borers and promotes consumption of the fodder.
4. Uneaten cornstalks, including corn stover in the field, lot or barn, or parts of the stalks, should be completely plowed under or burned before May 15, to destroy contained borers.
5. Fall plowing, especially early fall plowing, thoroughly done, kills many borers. Heavy rolling before plowing is suggested.
6. Burn weeds and grass in or near infested fields.
7. Early-planted corn is more likely to become infested, somewhat later planting usually results in relatively less injury. Early-planted corn should be closely watched and promptly fed to stock before the stalks begin to dry if it shows infestation.
8. In infested areas, planting of coarse-stemmed vegetables to be sold in green condition should not be closer than 50 feet to early corn.

To prevent the spread of this insect, strict State and Federal quarantine measures have been established, governing the transportation from infested areas, of plants or plant products, likely to contain the larvae.

Southern Corn Rootworm.—This pest is the larvae or young of the twelve-spotted cucumber beetle. Great injury is often done to corn of all kinds and to many other food plants in the South, including peanuts, beans and cucurbits. The injury to corn is done by the larvae in the spring when the plants are small. At this time they feed upon the roots and bud, boring through the crown at the base of the stalk to reach the bud. Injury is greatest when corn is planted in damp locations and in meadows.

When the insect is feeding upon the corn roots insecticides are of no value, but destruction of the beetles when they feed upon the aboveground portions of cucurbits and other plants will reduce the injury done by the larvae. Crop rotation, using cotton, small grains and vegetables other than beans and cucurbits will aid in controlling this insect.

Corn Smut (*Ustilago zeae*).—This disease occurs everywhere corn is grown and is easily recognized in the later stages as black masses upon

the ear and tassel. The first symptom is a pale shining, swollen area covered with a white membrane, which soon appears black due to the maturing of the spores on the inside. The membrane finally bursts and releases a powdery, black mass of spores. The disease is not carried on the seed.

There is no practicable control measure except to gather and burn the smutted ears and stalks before the spores are released. This method is usually not practiced because the disease seldom affects more than 1 to 2 per cent of the ears.

Harvesting.—Sweet corn, to have high quality, should be harvested in the milk stage, since the amount of sugar decreases and the amount of starch increases as it passes from this stage to the dough stage. The amount of water likewise decreases and the corn becomes harder. Analyses of Stowell's Evergreen sweet corn reported by Appleman (2) show the composition at various stages in the development of the kernels. While there was considerable difference in the composition of different samples representing any stage of ripening, the averages shown in Table LXVII indicate quite well the changes taking place during this period. Data were secured on two crops designated as "early" and "late."

Table LXVII.—Average Percentage Composition of Sweet Corn at Different Stages of Ripening

Crop	Stage of ripening	Number of tests	Moisture, per cent	Total sugar, per cent	Starch, per cent
Early	Premilk	9	85.10	6.26	3.29
Early	Milk	18	80.16	5.79	7.72
Early	Early dough	9	71.07	3.91	16.35
Early	Dough	18	63.92	3.17	21.62
Late	Premilk	14	88.75	5.76	2.71
Late	Milk	16	83.54	5.81	5.51
Late	Early dough	16	77.95	3.38	11.24

An examination of Table LXVII will show that as ripening proceeds the increase in the percentage of starch is greater than can be accounted for by the decrease in the percentage of sugar.

After sweet corn is harvested it should be handled quickly and at as low a temperature as possible for the quality deteriorates rapidly. There is a rapid loss of sugar at the temperatures that usually prevail during the corn-harvesting season, and only the home gardener can have sweet corn of the very best quality. Appleman and Arthur (3) and Stevens and Higgins (142) have shown that the rate of sugar loss increases with rise of temperature at least up to 30 degrees C. Appleman and

Arthur, working with Stowell's Evergreen conducted a series of experiments in which sweet corn was kept at seven accurately controlled temperatures, namely 0, 5, 20, 30 and 40 degrees C. Analyses were made to determine the loss of sugar during consecutive 24-hour periods of storage at these temperatures and the results are shown in Table LXVIII.

TABLE LXVIII.—LOSS OF SUGAR FROM GREEN SWEET CORN DURING CONSECUTIVE 24-HOUR PERIODS OF STORAGE AT DIFFERENT TEMPERATURES. TOTAL SUGARS AND LOSSES ARE EXPRESSED IN PERCENTAGES

(Appleman and Arthur)

All Sugars

Number of hours in storage	Ear lot	Storage temperatures									
		0 degrees C.		10 degrees C.		20 degrees C.		30 degrees C.		40 degrees C.	
		Total[1]	Loss[1]	Total[1]	Loss[1]	Total[1]	Loss[1]	Total[1]	Loss[1]	Total[1]	Loss[1]
0	1*a*	5.91	....	5.83	....	6.17	....	5.34	....	6.72	
24	1*b*	5.43	0.48	4.83	1.00	4.59	1.58	2.65	2.69	3.64	3.08
24	2*a*	6.70	....	3.95	....	3.68	....	3.11	....	2.30	
48	2*b*	5.96	0.74	3.43	0.52	2.69	0.99	2.68	0.43	1.69	0.61
48	3*a*	6.63	....	4.61	....	3.07	....	2.10	....	2.00	
72	3*b*	6.36	0.27	3.92	0.69	2.52	0.55	2.03	0.07	1.90	0.10
72	4*a*	6.10	....	3.54	....	2.24	....	1.59			
96	4*b*	5.75	0.35	2.93	0.61	1.97	0.27	1.49	0.10		

[1] Total quantities of all sugars before and after storage and losses during storage are expressed in percentages.

Summarizing the results of their work the authors have the following to say:

The depletion of sugar in green corn after it is separated from the stalk does not proceed at a uniform rate but becomes slower and slower until finally the loss of sugar ceases when the initial total sugar has decreased about 62 per cent and the sucrose about 70 per cent. Calculated on the basis of original moisture, the corn contained, when the depletion of sugar ceased, approximately 1.5 per cent total sugar as invert sugar, 0.7 per cent sucrose and 0.8 per cent free-reducing substances. The actual percentage of sugars would depend upon the amount of water in the corn after storage. Under the experimental conditions there was very little change in the percentage of water in the corn employed in this work.

Reversibility of the chief processes involved in the sugar depletion, resulting in an equilibrium between the rate of sugar loss and the rate of sugar formation, would account for the cessation of actual sugar loss. . . .

Raising the temperature simply hastens the attainment of the equilibrium positions, which seem to be about the same for all temperatures. At 30 degrees C., 50 per cent or most of the total sugar loss occurs during the first 24 hours of storage. At 20 degrees, 25 per cent and at 10 degrees, or good refrigerator temperature, only about 15 per cent is depleted during the same period. . . .

In general, it may be stated that the rate of sugar loss, until it reaches 50 per cent of the initial total sugar and 60 per cent of the sucrose, is doubled for every increase of 10 degrees up to 30 degrees C.

Respiration in green corn is comparatively high when the corn is first picked but falls off rapidly with storage. This process, however, accounts for only a small part of the actual decrease in the percentage of sugar in the corn during the consecutive 24-hour periods of storage even at 30 degrees C. One ton of husked green sweet corn during the first 24 hours of storage at 30 degrees would lose approximately 3.2 pounds of sugar on account of respiration.

Respiration may become indirectly a more important factor in accelerating the depletion of sugar by raising the temperature on the inside of large piles of green corn.

Most of the decrease in the percentage of sugar in green sweet corn during storage is due to condensation of polysaccharides, chiefly starch.

Sweet corn often becomes heated after being pulled from the stalk, especially when loaded into tight wagon beds for hauling to the canning factory. The load often stands over night. Under such conditions the quality deteriorates rapidly, and while the sugar loss is made up by the addition of sugar when the corn is prepared for canning the product is not as good as when it is canned before it has changed in composition.

It is difficult for the inexperienced to determine when sweet corn is in the best edible condition without pulling down the husk and examining the kernels. The general appearance of the husk and silk, and the plumpness of the ear are evidences of the stage of ripeness, and are sufficient for the average grower. By observing the general characters mentioned and correlating them with the stage of ripeness, as indicated by the nail test, the inexperienced will soon learn to determine when sweet corn should be harvested without examining the kernels. In the nail test the thumb-nail is thrust into the kernel, and if the exudate is milky the corn is said to be in the milk stage. If dough is forced out of the kernel by the nail the corn is said to be in the dough stage and is too ripe for the best quality.

The ears are usually pulled from the stalk by a quick jerk, and if the stalk at the base of the ear is too long it is broken off. All ears should have about the same length of stalk and the same amount of husk. The corn harvested for market is usually placed in boxes, baskets, or bags as removed from the stalk and these are later placed on a wagon. For the canning factory the ears are sometimes thrown direct to the wagon bed.

Grading and Packing for Market.—Sweet corn is, as a rule, not very carefully graded, but the best growers do grade and find that it is a very desirable practice. Grading is especially important where the ears are put up in packages and of course, a package should contain only one grade. The best grade should contain ears of medium size and uniform in every particular.

Since market sweet corn is grown mainly by market gardeners the use of closed packages is not very common. All types of containers are used for conveying corn to local markets. Some markets use bushel boxes, others use baskets of various kinds, while some use special crates. Bags are sometimes used but they are the least desirable type of container, since they do not show off the corn to good advantage and they also interfere with the circulation of air.

When sweet corn is to be shipped considerable distances the ears should be carefully packed in a well-ventilated crate or box and loaded into refrigerator cars. Even with the closest attention to these factors there is considerable deterioration in quality when the product is in transit two days or more.

OKRA

Okra or gumbo is an important crop in many parts of the Old World, where it is used in the dried form in large quantities. In the United States it is not of great commercial importance, although it is a popular vegetable in the South, where it is grown quite generally in the home garden. The Bureau of Census reports the value of okra grown for sale in the United States in 1919 as $117,175 and an average value per acre of $119.

History and Taxonomy.—Okra is thought to be of African, or Asiatic origin, probably both. It was probably not cultivated during ancient times as it is not mentioned in the early literature. It was known by the Spanish Moors and was used by the Egyptians in the twelfth or thirteenth century. Okra is mentioned as having been grown in Philadelphia in 1748 and was listed by Jefferson in 1781 as being grown in Virginia. McMahon (1806) also mentions its culture in the South.

Okra is known under the botanical name *Hibiscus esculentum* L., and belongs to the Malvaceae or mallow family. Many other species of hibiscus are used as foods in various parts of the world. In this genus belongs many species of flowering hibiscus, several of which are native of the United States. Cotton is the most important economic plant belonging to the mallow family.

Culture.—Okra is a tender plant and grows best in hot weather. In regions having a short growing season and relatively cool nights the crop does not thrive well. In such regions a supply for home use can be grown if quick-maturing, dwarf varieties are selected, and the seed is planted as soon as the soil becomes warm.

In the South two or three plantings, at intervals of 3 to 4 weeks apart, are sometimes made in order to have a continuous supply from the time the first pods are ready until frosts occur in the fall. However, if the pods are gathered while they are still young and tender and if none

are allowed to mature the plants will continue bearing for a considerable period.

Seed is drilled quite thickly in rows 2½ to 4 feet apart. When the plants are established they are thinned to stand 12 inches apart for dwarf varieties and 18 to 24 inches for the large varieties.

Any good garden soil will produce a satisfactory crop of okra if other conditions are favorable. If the soil is not rich a liberal application of fertilizer or manure is desirable. A complete fertilizer high in nitrogen is recommended for the average sandy loam soil where manure is not used. An application of 500 to 1,000 pounds to the acre of a 5–10–5 mixture is suggested.

The cultivation given okra should be about the same as for any other cultivated crop.

Varieties.—Beattie (11) states that there are three general types of okra, tall green, dwarf green and lady finger.

"Each of these is again divided according to the length and color of the pods, making in all six classes or varieties, namely, tall green, long pod; tall green, short pod; dwarf green, long pod; dwarf green, short pod; lady finger, white pod and lady finger, green pod. All variations from these are merely the results of mixtures, no true crosses or hybrids being formed. These mixtures are easily separated and referred to the parent type, and a little attention to rogueing and selection is necessary in order to keep the varieties pure. It is essential that the varietal strain should be pure in order that a uniform and marketable lot of pods may be produced."

There are relatively few varieties listed by the seedsmen. Many seedsmen mention White Velvet, Perkins Mammoth, Dwarf Green and Lady Finger.

Harvesting.—The long seed pods are the edible portion, and as these develop rapidly, they should be gathered every day. Only the young tender pods are desired as the older pods become woody and tough. They are broken or cut from the stalk, and when they are to be marketed they should be sorted into the various sizes and packed in small baskets. The pods become tough quickly after being removed from the plant and, for this reason, they should be placed on the market as soon as possible. Shipping to distant markets is not a common practice because the pods do not remain in good condition for a sufficient length of time.

Uses of Okra.—The principal use of okra is in soups and stews, in which meats form an important part, as in the so-called gumbo soups. The pods are sometimes stewed and eaten as a vegetable, being seasoned with pepper, salt and butter. Okra is sometimes canned, either alone, or in a soup mixture with other vegetables. Okra or gumbo soup is very much relished by persons who have acquired a taste for it and it is a fairly common article of diet in the South.

In Turkey the young pods of okra are dried in large quantities for use in the diet. Many tons of the dried product are brought into the United States each year in order to meet the demand among the foreign population, especially the Turks.

MARTYNIA

Martynia or Unicorn Plant, *Martynia proboscidea* (*Martynia Louisiana or Proboscidea Louisiana*) is a native of south-western United States. It is grown to a very slight extent in home gardens mainly as a curiosity, but its

FIG. 32.—Martynia plant and fruit.

seed pods are used for pickling when young. The pods are green, very hairy, fleshy, 1½ inches at their greatest diameter tapering to a long, slender incurved beak or horn. (Fig. 32.) The plant grows 1½ to 2 feet high and is rather wide spreading.

In the South, Martynia seed may be sown in rows 3 feet apart and the plants thinned to stand 18 to 24 inches apart in the row. In the North the plants should be started in the greenhouse and later transplanted to the garden. A warm soil is especially desirable in the North. The general cultural requirements of this plant are about the same as for okra.

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